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EFFECTS OF NITROGEN FERTILIZATION AND FREQUENCY OF CUTTING ON THE YIELD AND COMPOSITION OF NAPIER GRASS IN PUERTO RICO. *José Vicente-Chandler, Servando Silva, and Jacinto Figarella* 215

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# THE JOURNAL OF AGRICULTURE
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# Effects of Nitrogen Fertilization and Frequency of Cutting on the Yield and Composition of Napier Grass in Puerto Rico[1]


*José Vicente-Chandler, Servando Silva, and Jacinto Figarella*[2]


## INTRODUCTION

Napier or elephant grass (*Pennisetum purpureum* Schum.) (fig. 1) is probably the highest yielding and one of the most widely used tropical grasses. Dairy cows in Puerto Rico are fed almost exclusively on cut Napier grass supplemented with concentrates. This grass is often grown on very expensive land near the large urban areas where most of the dairies are located. In densely populated Puerto Rico, with about 650 persons per square mile, many are forced to keep the family cow on a small patch of land near the house. In both cases it is essential to obtain maximum yields of forage per unit area.

There is very little information on the response of Napier grass to nitrogen fertilization. Studies have generally been limited to the effects of manuring or of very light applications of nitrogen on the productivity of this grass. In Puerto Rico, Rodríguez (*4*),[3] found that applications of 200 pounds of nitrogen per acre yearly more than doubled yields of Napier grass, while Vicente, *et al.* (*5*), suggested that the application of 400 or more pounds of nitrogen per acre yearly to Napier may be warranted.

The effect of frequency of cutting on the yield and composition of Napier grass, however, has received considerable attention. Wilsie (*7*), in Hawaii, found that yields increased, but protein, phosphorus, and calcium content decreased progressively as harvest interval was lengthened from 6 to 14 weeks. Watkins and Lewy (*6*), in San Salvador, and Patterson (*2*), in Trinidad, obtained similar results and the latter also reported that the crude-fiber content of the forage increased with length of harvest interval.


[1] This work was carried out cooperatively between the U. S. Department of Agriculture and the Agricultural Experiment Station of the University of Puerto Rico.



[2] Project Supervisor, Physical Science Aid, and Soil Scientist, respectively, Soil and Water Conservation Research Division, Agricultural Research Service, U. S. Department of Agriculture.


[3] Italic numbers in parentheses refer to Literature Cited, p. 227.

Rivera-Brenes (*3*) in Puerto Rico, however, reported that higher yields were obtained when Napier grass was cut at 40- rather than 90-day intervals, and that the lignin content of the forage increased and protein, ash, and carotene content decreased with length of the harvest interval.

This paper presents the results of an experiment carried out to characterize the response of Napier grass to nitrogen fertilization as affected by

FIG. 1.—Sixty-day-old Napier grass ready for cutting. When this grass was properly fertilized about 130 tons of green forage, or 44,561 pounds of dry matter, having a crude-protein content of 9.7 percent, were produced per acre yearly.

frequency of cutting and season of the year. The effects of treatments on forage composition and on soil acidity were also studied.

## MATERIALS AND METHODS

The experiment was carried out at Río Piedras over three consecutive years. The mean annual temperature is about 76° F. with seasonal variations of less than 10° F. Annual rainfall was 62.8, 93.4, and 57.4 inches for the first, second, and third years of experimentation, respectively.

The soil is a Toa clay loam, which is a deep, well-drained, alluvial soil. Initially, the surface 6 inches averaged 2.9 percent of organic matter, 0.15 percent of nitrogen, 20.3 m.e. exchange capacity, and 16.5 m.e. of exchangeable bases per 100 gm. of soil, and had a pH of 5.1.

The treatments used were as follows:

| *Harvest intervals (Days)* | *Nitrogen levels (Pounds N per acre yearly)* |
|---|---|
| 40 | 0 |
| | 200 |
| 60 | 400 |
| | 800 |
| 90 | 1,200 |
| | 2,000 |

All combinations of these treatments were tested using a split-plot design with harvest intervals as the main plots and nitrogen levels as the subplots. All treatments were replicated four times. Subplots were 15 x 18 feet, surrounded by ditches to prevent fertilizer from washing into adjoining plots.

The upper 6 inches of soil in all plots was limed to a pH of about 7 at the start of the experiment. Blanket additions of phosphorus and potassium were made at a rate of 300 pounds $P_2O_5$ from 20-percent superphosphate per acre in one annual application, and 600 pounds $K_2O$ from KCl per acre annually, in four to nine equal applications, depending on frequency of cutting. The nitrogen was applied as ammonium sulfate in four to nine equal applications yearly, depending on frequency of cutting.

The grass was cut at the prescribed intervals, weighed, and the forage removed from the plots. Samples from each plot at every harvest were analyzed for dry matter and total nitrogen. The crude-protein content was calculated using the factor 6.25 times N. Samples were composited by plots at the end of the first year and analyzed for calcium, phosphorus, potassium, magnesium, and lignin. During the third year, yields only were determined. Yields were taken over two 60-day periods after terminating the experiment to determine the residual effects of the treatments.

At the end of the experiment the soil in all plots cut every 60 days and receiving 0, 800, and 1,200 pounds of nitrogen per acre yearly was sampled at 6-inch intervals to a depth of 4 feet and the pH and exchangeable bases determined.

## RESULTS

### EFFECT OF LENGTH OF HARVEST INTERVAL

The data in table 1 and figure 2 show that yields increased greatly with length of harvest interval. At the 800-pound level of nitrogen, Napier grass produced 24,520, 44,561, and 75,661 pounds of dry matter per acre yearly, when cut at 40-, 60-, and 90-day intervals, respectively. The dry-matter content of the forage also increased with the harvest interval, averaging 14.1, 17.1, and 25.1 percent, respectively, for these intervals.

The protein content of the forage, however, decreased markedly with length of harvest interval, averaging at the 800-pound level of nitrogen, 12.9, 9.7, and 6.9 percent when the grass was cut at 40-, 60-, and 90-day intervals, respectively.

TABLE 1.—*The effects of nitrogen fertilization and frequency of cutting on the yield and protein content of Napier grass and on the efficiency of utilization of the applied nitrogen, over a 2-year period*

| Nitrogen applied per acre yearly | Yield of green forage per acre yearly | Yield of dry matter per acre yearly | Crude-protein content | Crude-protein yield per acre yearly | Recovery of N in forage | Dry matter produced per pound of each increment of N |
|---|---|---|---|---|---|---|
| | | | *Grass cut every 40 days* | | | |
| *Lb.* | *Lb.* | *Lb.* | *Percent* | *Lb.* | *Percent* | *Lb.* |
| 0 | 65,799 | 9,586 | 8.3 | 798 | — | — |
| 200 | 105,701 | 15,213 | 8.9 | 1,353 | 44.5 | 28.1 |
| 400 | 140,498 | 20,300 | 9.9 | 2,003 | 48.2 | 25.4 |
| 800 | 173,996 | 24,520 | 12.9 | 3,177 | 48.4 | 10.5 |
| 1,200 | 225,698 | 31,606 | 14.9 | 4,711 | 52.2 | 17.7 |
| 2,000 | 201,712 | 26,943 | 17.6 | 4,753 | 31.6 | — |
| | | | *Grass cut every 60 days* | | | |
| 0 | 92,343 | 15,150 | 6.5 | 983 | — | — |
| 200 | 148,754 | 24,617 | 7.2 | 1,780 | 63.8 | 47.3 |
| 400 | 214,993 | 36,727 | 7.9 | 2,892 | 76.4 | 60.6 |
| 800 | 259,911 | 44,561 | 9.7 | 4,329 | 66.9 | 19.6 |
| 1,200 | 273,282 | 46,578 | 11.9 | 5,556 | 61.0 | 5.0 |
| 2,000 | 276,025 | 46,616 | 13.8 | 6,437 | 43.6 | — |
| | | | *Grass cut every 90 days* | | | |
| 0 | 136,301 | 30,431 | 5.4 | 1,649 | — | — |
| 200 | 182,530 | 42,710 | 4.9 | 2,092 | 35.4 | 61.4 |
| 400 | 230,376 | 56,517 | 5.4 | 3,054 | 56.2 | 69.0 |
| 800 | 300,900 | 75,661 | 6.9 | 5,218 | 71.4 | 47.9 |
| 1,200 | 288,183 | 69,531 | 8.2 | 5,673 | 53.7 | — |
| 2,000 | 316,229 | 76,659 | 9.6 | 7,377 | 45.8 | .8 |

Protein yields increased with length of harvest interval, averaging at the 800-pound level of nitrogen, 3,177, 4,329, and 5,218 pounds per acre yearly when the grass was cut at 40-, 60-, and 90-day intervals, respectively.

Generally, more of the applied nitrogen was recovered when the grass was cut every 60 days, while the dry matter produced per pound of fertilizer nitrogen tended to increase with length of harvest interval.

The lignin content of the forage increased with length of harvest interval,

averaging 7.17, 8.72, and 10.78 percent when the grass was cut every 40, 60, and 90 days, respectively.

The data in table 2 show that the phosphorus and potassium contents of the forage decreased sharply with length of the harvest interval, while the calcium and magnesium contents showed a similar tendency. The phosphorus content of the forage averaged 0.46, 0.35, and 0.26 percent, the calcium content 0.36, 0.29, and 0.27 percent, the magnesium content 0.28, 0.21, and 0.19 percent, and the potassium content 2.73, 1.94, and 1.26 percent with a 40-, 60-, and 90-day harvest interval, respectively.

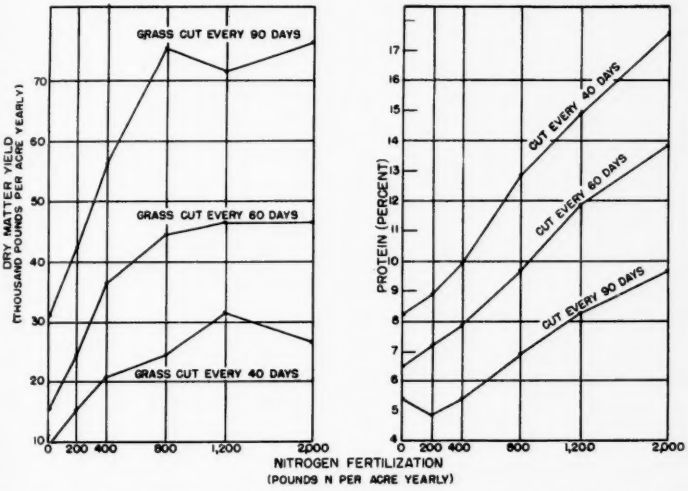
GRASS CUT EVERY 90 DAYS
GRASS CUT EVERY 60 DAYS
GRASS CUT EVERY 40 DAYS
DRY MATTER YIELD (THOUSAND POUNDS PER ACRE YEARLY)
PROTEIN (PERCENT)
CUT EVERY 40 DAYS
CUT EVERY 60 DAYS
CUT EVERY 90 DAYS
0 200 400 800 1,200 2,000
NITROGEN FERTILIZATION (POUNDS N PER ACRE YEARLY)

FIG. 2.—Effects of nitrogen fertilization and frequency of cutting on yield and protein content of Napier grass.

Less weeding was required with the longer harvest intervals. Plots receiving 800 pounds of nitrogen per acre yearly had to be weeded 1, 3, and 6 times a year when cut at 90-, 60-, and 40-day intervals, respectively.

## EFFECT OF NITROGEN FERTILIZATION

The data in table 1 and figure 2 show that yields increased rapidly with nitrogen fertilization up to the 800-pound level at all harvest intervals. With a 60-day interval, yields were about tripled to 44,561 pounds of dry matter, or about 130 tons, of green forage per acre yearly by the application of 800 pounds of nitrogen. Detailed analysis of the data shows that a strong response in yield up to this level of nitrogen occurred at all seasons of the year.

The protein content of the forage increased with nitrogen fertilization

TABLE 2.—*The effects of nitrogen fertilization and harvest interval on the mineral and lignin content of Napier grass and on withdrawal of nutrients in forage*[1]

| Nitrogen fertilization (pounds N per acre yearly) | Results at harvest intervals indicated | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 40 days | | 60 days | | 90 days | | Average | |
| | Percentage composition[2] | Pounds withdrawn per acre yearly | Percentage composition[2] | Pounds withdrawn per acre yearly | Percentage composition[2] | Pounds withdrawn per acre yearly | Percentage composition[2] | Pounds withdrawn per acre yearly |
| | | | | *Nitrogen* | | | | |
| 0 | 1.25 | 127.4 | 0.94 | 152.6 | 0.75 | 171.2 | 0.98 | 150.4 |
| 400 | 1.58 | 344.5 | 1.33 | 499.9 | .88 | 417.7 | 1.28 | 420.7 |
| 800 | 1.98 | 503.5 | 1.52 | 674.3 | 1.02 | 688.1 | 1.51 | 622.0 |
| Average | 1.60 | 325.2 | 1.26 | 442.3 | 0.88 | 425.7 | | |
| | | | | *Phosphorus* | | | | |
| 0 | 0.59 | 60.1 | 0.43 | 69.8 | 0.34 | 77.6 | 0.45 | 69.2 |
| 400 | .48 | 104.6 | .36 | 135.3 | .26 | 123.4 | .37 | 121.1 |
| 800 | .32 | 81.4 | .27 | 119.8 | .19 | 128.2 | .26 | 109.8 |
| Average | 0.46 | 82.1 | 0.35 | 108.3 | 0.26 | 109.7 | | |
| | | | | *Calcium* | | | | |
| 0 | 0.38 | 38.7 | 0.32 | 52.0 | 0.29 | 66.2 | 0.33 | 52.3 |
| 400 | .35 | 76.3 | .28 | 105.2 | .23 | 109.2 | .29 | 96.9 |
| 800 | .35 | 89.0 | .27 | 119.8 | .29 | 263.1 | .30 | 157.3 |
| Average | 0.36 | 68.0 | 0.29 | 92.3 | 0.27 | 146.2 | | |
| | | | | *Potassium* | | | | |
| 0 | 3.94 | 401.5 | 2.81 | 456.3 | 2.02 | 461.2 | 2.92 | 439.6 |
| 400 | 2.39 | 521.1 | 1.77 | 665.3 | 1.06 | 503.2 | 1.74 | 563.2 |
| 800 | 1.87 | 475.6 | 1.25 | 554.5 | .70 | 472.2 | 1.27 | 500.8 |
| Average | 2.73 | 465.9 | 1.94 | 558.7 | 1.26 | 478.8 | | |
| | | | | *Magnesium* | | | | |
| 0 | 0.18 | 18.3 | 0.18 | 29.2 | 0.17 | 38.8 | 0.18 | 28.8 |
| 400 | .30 | 65.4 | .19 | 71.4 | .19 | 90.2 | .23 | 75.7 |
| 800 | .35 | 89.1 | .27 | 119.8 | .22 | 148.4 | .28 | 119.1 |
| Average | 0.28 | 57.6 | 0.21 | 73.5 | 0.19 | 92.5 | | |
| | | | | *Lignin* | | | | |
| 0 | 6.65 | — | 7.92 | — | 9.58 | — | 8.05 | — |
| 400 | 6.94 | — | 8.81 | — | 11.13 | — | 8.96 | — |
| 800 | 7.93 | — | 9.44 | — | 11.63 | — | 9.67 | — |
| Average | 7.17 | — | 8.72 | — | 10.78 | — | | |

[1] All values are averages of 4 replicates composited from all cuttings over a full 1-year period.

[2] On dry-weight basis.

up to the highest level tested, averaging when cut every 60 days, 6.5, 7.9, 9.7, and 13.8 percent when fertilized with 0, 400, 800, and 2,000 pounds of nitrogen per acre yearly, respectively. The highest protein content of 17.6 percent was attained with a 40-day harvest interval and 2,000 pounds of nitrogen per acre yearly. The assumption is made that the nitrogen was essentially all in the amino form, since no more than traces of nitrates were found in the forage.

Protein yields increased rapidly with nitrogen fertilization up to the maximum level tested, averaging with a 60-day harvest interval, 983, 4,329, and 6,437 pounds per acre yearly, when fertilized with 0, 800, and 2,000 pounds of nitrogen per acre yearly, respectively.

The data in table 1 show that a high proportion of the fertilizer nitrogen was recovered in the forage. With a 60-day harvest interval, 76.4, 66.9, and 61.0 percent of the 400-, 800-, and 1,200-pound applications of nitrogen, respectively, was recovered in the forage. When residual yields are considered, recovery of fertilizer averages about 5-percent higher. Napier grass obtained about 150 pounds of nitrogen per acre yearly from the soil when no nitrogen was applied. The efficiency of utilization of applied nitrogen dropped rapidly beyond the 400-pound level. With a 60-day harvest interval, 47.3, 60.6, 19.6, and 5 pounds of dry matter were produced per pound of each successive increment of nitrogen.

The data in table 2 show that the phosphorus and potassium contents of the forage decreased significantly with increased nitrogen rates at all harvest intervals, but the calcium and magnesium contents were not greatly affected by nitrogen fertilization. With a 60-day harvest interval the phosphorus content of the forage was 0.43, 0.36, and 0.27 percent and the potassium content 2.81, 1.77, and 1.25 percent at the 0-, 400-, and 800-pound levels of nitrogen respectively.

The lignin content of the forage increased with nitrogen fertilization, averaging when cut every 60 days, 7.92, 8.81, and 9.44 percent at the 0-, 400-, and 800-pound levels of nitrogen, respectively.

Nitrogen fertilization reduced weed growth. Plots cut every 60 days and receiving no nitrogen had to be weeded after each harvest, while those receiving 800 pounds or more of nitrogen required only three light weedings a year.

## NUTRIENT WITHDRAWAL AT HIGH YIELD LEVELS

Table 3 shows that intensively managed Napier grass withdraws very large amounts of nutrients and, therefore, heavy fertilization is required to sustain high yields. Withdrawal of nitrogen and potassium was particularly high with 674 and 554 pounds, respectively, withdrawn per acre yearly. Heavier applications of fertilizer than indicated are required to compensate for losses by leaching, fixation, etc.

Table 2 shows that nutrient withdrawal generally followed yields, increasing with nitrogen rates and length of harvest intervals. For example, withdrawal of calcium was more than tripled, that of phosphorus was about doubled and that of nitrogen was more than quintupled when the harvest interval was increased from 40 to 60 days and nitrogen rates from 0 to 800 pounds per acre yearly.

## RESIDUAL EFFECTS ON YIELDS

Plots harvested at longer intervals during the course of the experiment produced higher residual yields. Plots harvested at 40-, 60-, and 90-day intervals during the course of the experiment yielded 2,921, 3,389, and 4,284 pounds of dry matter per acre, respectively, over a 60-day period ending 4 months after the experiment was terminated.

TABLE 3.—*Withdrawal of nutrients by intensively managed Napier grass producing 44,561 pounds of dry matter per acre yearly*

| Nutrients | Pounds withdrawn per acre yearly | Equivalent to— |
|---|---|---|
| Nitrogen | 674 | 3,300 lb. ammonium sulfate |
| Phosphorus | 120 | 1,350 lb. 20-percent superphosphate |
| Potassium | 554 | 1,100 lb. potassium chloride |
| Calcium | 120 | 300 lb. limestone |
| Magnesium | 120 | 600 lb. magnesium sulfate |

Higher residual yields were produced by plots receiving heavy nitrogen applications during the course of the experiment. The following tabulation shows the effect of nitrogen rates used during the course of the experiment on yields and protein content of forage produced over a 60-day period, ending 6 months after the last application of nitrogen.

| *Nitrogen level* | *Pounds dry matter per acre* | *Percent protein* |
|---|---|---|
| 0 | 1,270 | 7.1 |
| 200 | 2,002 | 7.1 |
| 400 | 2,997 | 7.8 |
| 800 | 3,839 | 8.2 |
| 1,200 | 7,431 | 11.2 |
| 2,000 | 8,958 | 13.3 |

## EFFECT OF SEASON OF THE YEAR

Figure 3 shows that season of the year had a strong effect on forage production with yields varying from the average by as much as 70 percent. January, February, and March yields were below average, while May, June, July, and August yields were above average during all three years.

Season of the year also had a marked effect on protein content of the forage which varied, with a 60-day harvest interval and 800-pound level of nitrogen, from as low as 7.4 to as high as 12.9 percent. In general, highest protein contents were found during seasons of slow growth, and vice versa.

High production was maintained throughout the 3-year course of the experiment provided the grass was properly managed. The yields of plots receiving no nitrogen, however, dropped off every year, as did those of the lightly fertilized plots cut every 40 days. The data in figure 3 show that, with proper management, yields during the driest year on record (1957) were only about 17 percent less than during the very wet year of 1956.

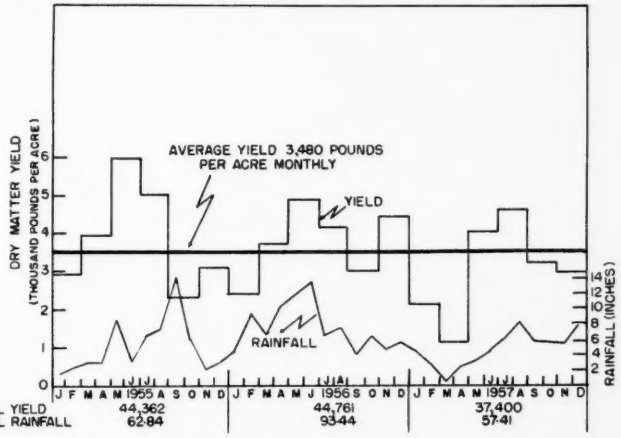
DRY MATTER YIELD (THOUSAND POUNDS PER ACRE)
AVERAGE YIELD 3,480 POUNDS PER ACRE MONTHLY
YIELD
RAINFALL
RAINFALL (INCHES)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1955
1956
1957
ANNUAL YIELD 44,362 44,761 37,400
ANNUAL RAINFALL 62·84 93·44 57·41

FIG. 3.—Effect of season of the year and of rainfall on yield of Napier grass cut every 60 days and fertilized with 800 pounds of nitrogen per acre yearly.

## EFFECT OF HEAVY APPLICATIONS OF AMMONIUM SULFATE ON SOIL REACTION AND BASE STATUS

Heavy applications of ammonium sulfate had a tremendous effect on soil acidity and base status as shown by the data in table 4 and discussed in detail by Abruña, Pearson, and Elkins (*1*). The application of 800 pounds of nitrogen as ammonium sulfate per acre yearly for three consecutive years reduced the pH of the upper 6 inches of soil from 7.0 to 4.1, and the exchangeable base content from 21.9 to 11.5 m.e. per 100 gm. of soil. At the 1,200-pound level of nitrogen the pH was further reduced to 3.5 and the exchangeable bases to 4 m.e. per 100 gm. of soil. At this rate of nitrogen fertilization the base status of the soil was affected to a depth of 2 feet in the profile. There was no indication of an accumulation of bases in the lower horizons of soil.

## DISCUSSION

Although highest yields were obtained when Napier grass was cut every 90 days, the forage was of poor quality as indicated by its low protein and mineral, and high lignin contents. With the 40-day harvest interval, on the other hand, quality of the forage was excellent but yields were relatively low, it was difficult to maintain a good stand, frequent weeding was necessary, and cost of harvesting was higher. A 60-day harvest interval would seem to be a reasonable compromise between high yields and ease of management on one hand and quality of forage on the other.

The application of up to 800 pounds of nitrogen per acre yearly appears economical under the conditions of this experiment. About 10 pounds of

TABLE 4.—*The effect of nitrogen fertilizer in the form of ammonium sulfate on the reaction and exchangeable-base status at different depths of a Toa clay loam planted to Napier grass, over a 3-year period*

| Depth (inches) | pH for— | | | M.e. exchangeable bases per 100 gm. of soil for— | | |
|---|---|---|---|---|---|---|
| | No N | 800 lb. N per acre yearly | 1,200 lb. N per acre yearly | No N | 800 lb. N per acre yearly | 1,200 lb. N per acre yearly |
| 0–6 | 7.0 | 4.1 | 3.5 | 21.9 | 11.5 | 4.0 |
| 6–12 | 6.1 | 5.0 | 4.1 | 20.6 | 17.5 | 9.0 |
| 12–18 | 5.6 | 5.2 | 4.3 | 17.7 | 17.7 | 11.9 |
| 18–24 | 5.6 | 5.6 | 4.8 | 18.3 | 17.5 | 16.2 |
| 24–36 | 5.9 | 5.9 | 5.9 | 21.4 | 21.1 | 19.8 |
| 36–48 | 6.1 | 6.0 | 5.9 | 21.1 | 20.4 | 20.4 |

[1] All values are averages of 4 replications.

dry forage of fair quality is required to produce a 1-pound gain in weight—worth 16 cents—with young steers, and nitrogen is worth about 15 cents a pound in Puerto Rico. This is on the assumption that the break-even point is that at which each pound of nitrogen produced 15 pounds of dry forage. It appears from table 1 that applications of up to 800 pounds of nitrogen would be definitely profitable with a 60-day harvest interval. Similar calculations in terms of milk production would, of course, show a wider profit margin. Also, the cost of nitrogen could be greatly reduced by using anhydrous ammonia on mechanizable lands. Other important considerations are the increased protein content of the forage, the high proportion of fertilizer nitrogen recovered, and the reduced growth of weeds at this level of nitrogen.

Thus, about a 60-day harvest interval and 800 pounds of nitrogen per acre yearly appear best for Napier grass under the conditions of this

experiment. About 130 tons of green forage, or 44,561 pounds, of dry matter having a protein content of 9.7 percent were produced per acre yearly with this treatment. This is sufficient to meet the roughage requirements of more than 6 mature cows or steers.

Yields of this magnitude can be obtained with proper management under the widely different soil and climatic conditions found on the Island, provided moisture is adequate. In other experiments by the authors, Napier grass yielded 32,900 pounds of dry matter per acre yearly on a steep clay soil in the mountain region, and 51,491 pounds on a very fertile, irrigated soil on the semiarid south coast.

The increase in lignin content and decrease in protein content of the forage with length of harvest interval is a normal result of maturity. The decrease in mineral content may have been caused partly by the dilution effect of higher yields in the presence of a relatively constant amount of available minerals in the soil, as well as by maturity.

The increase in protein content with nitrogen fertilization is to be expected but the concurrent increase in lignin content is difficult to explain. The decrease in phosphorus and potassium contents with increased nitrogen fertilization is probably again a reflection of the dilution effect. The calcium and magnesium contents did not follow the same pattern, probably due to an abundance of these nutrients in the soil.

Several factors were apparently responsible for the variable productivity of Napier grass at different seasons of the year (fig. 3). Although rainfall was clearly an important factor, it does not explain all the differences. For example, during January, February, and March of 1956, with a total of 21.1 inches of rain, yields were no higher than during the same period of 1955, with only 7.4 inches of rain. Also, yields during the last 2 months of 1956 with 11 inches of rain were almost twice as high as during the first 2 months of 1956 with 14.5 inches of rain. Apparently, the shorter days and somewhat cooler weather at the beginning of the year contributed towards slowing the growth rate of Napier grass.

The data suggest that variations in forage production throughout the year could be kept within a range of about 30 percent of the average by using a longer harvest interval and heavier nitrogen fertilization during seasons of slow growth and a shorter harvest interval and lighter fertilization during seasons of fast growth.

The heavy losses of soil bases occurring with the application of 2 tons of ammonium sulfate (800 pounds of nitrogen) per acre yearly are equivalent to about 2½ tons of calcium carbonate per acre yearly. This loss may be reduced by using a source of nitrogen having a lower residual acidity. If residually acid sources are used, annual applications of limestone would help to prevent loss of bases deep in the profile.

## SUMMARY

The effects of nitrogen rates ranging from 0 to 2,000 pounds of N per acre yearly and of 40-, 60-, and 90-day harvest intervals on the yield and composition of Napier grass and on soil acidity, were determined for three consecutive years.

Yields increased with nitrogen fertilization to at least the 800-pound level during all seasons. Crude-protein contents and protein yields increased with nitrogen fertilization up to the 2,000-pound level. More than 60 percent of the fertilizer nitrogen was recovered in the forage at all rates up to 1,200 pounds per acre yearly, but efficiency of utilization in terms of dry matter produced per pound of nitrogen decreased beyond the 400-pound level. The phosphorus and potassium contents of the forage decreased, but the lignin content increased with increasing nitrogen rates. The calcium and magnesium contents were not markedly affected by nitrogen fertilization.

Dry-matter and protein yields and lignin content of the forage increased, while the protein, phosphorus, calcium, magnesium, and potassium contents decreased with length of harvest interval.

With a 60-day harvest interval and 800 pounds of nitrogen per acre yearly, which seemed to be the optimum combination, Napier grass yielded 44,561 pounds of dry matter, or about 130 tons of green forage, per acre yearly, containing 9.7 percent of protein. With this treatment, Napier grass removed 674 pounds of nitrogen, 554 of potassium, and 120 each of calcium, magnesium, and phosphorus per acre yearly from the soil.

Over-all yields did not decrease during the 3 years of experimentation but seasonal yields varied by as much as 70 percent of the average. The treatments affected residual yields obtained more than 6 months after the experiment was terminated.

The application of 800 pounds of N as ammonium sulfate per acre annually over a 3-year period caused a drop of 3 pH units and a loss of 10.4 m.e. of exchangeable bases per 100 gm. of soil in the upper 6 inches of soil.



## RESUMEN

Se estudió el efecto de aplicaciones de nitrógeno que variaban entre 0 y 2,000 libras por cuerda por año y de intervalos de corte de 40, 60, y 90 días, en el rendimiento y composición de la yerba Napier, o Elefante (*Pennisetum purpureum* Schum.), y en la acidez del suelo durante 3 años consecutivos.

Los rendimientos aumentaron con niveles de nitrógeno hasta 800 libras por cuerda por año. El contenido y rendimiento de proteína aumentó con niveles de nitrógeno hasta 2,000 libras por cuerda por año. Se recuperó en el forraje más del 60 por ciento del nitrógeno aplicado hasta 1,200 libras por cuerda, pero la eficiencia de utilización expresada en términos de

forraje seco producido por cada libra de nitrógeno disminuyó cuando se aplicaron más de 400 libras por cuerda. El contenido de fósforo y potasio disminuyó pero el de lignina aumentó al aumentar los niveles de nitrógeno. El contenido de calcio y magnesio en el forraje no se afectó señaladamente con las aplicaciones de nitrógeno.

Los rendimientos de forraje seco y de proteína, y el contenido de lignina del forraje aumentó al alargarse los intervalos de corte. Sin embargo, el contenido de proteína, fósforo, calcio, magnesio, y potasio disminuyó según se alargaron los intervalos de corte.

Con un intervalo de corte de 60 días y 800 libras de nitrógeno por cuerda por año, que parece ser el tratamiento óptimo, la yerba Napier produjo 44,561 libras de materia seca (como 130 toneladas de forraje verde) por cuerda por año, con un contenido de proteína de 9.7 por ciento. Con este tratamiento, la yerba extrajo del suelo 674 libras de nitrógeno, 554 libras de potasio y 120 libras de calcio, magnesio, y fósforo por cuerda por año.

El rendimiento no disminuyó durante los 3 años de experimentación, pero la producción varió hasta un 70 por ciento del promedio durante distintas épocas del año. Los tratamientos afectaron el crecimiento de la yerba aún hasta 6 meses después de terminar los experimentos.

La aplicación de 800 libras de nitrógeno, en forma de sulfato amónico, por cuerda por año, durante 3 años, redujo el pH de las 6 pulgadas de superficie hasta 3 unidades completas y acarreó una pérdida de 10.4 miliequivalentes de bases intercambiables por cada 100 gramos de suelo.

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# Effects of Nitrogen Fertilization and Frequency of Cutting on the Yield and Composition of Guinea Grass in Puerto Rico[1]

*José Vicente-Chandler, Servando Silva, and Jacinto Figarella*[2]

## INTRODUCTION

Guinea grass (*Panicum maximum*) (fig. 1) is one of the most widely used and versatile forage grasses of the Tropics, thriving under widely varying soil and climatic conditions. In Puerto Rico, it is the most extensively used of the improved grasses. On this densely populated Island, it is essential that high yields of forage be produced per unit of land.

Despite the importance of Guinea grass as a forage crop, little is known regarding the effects of nitrogen fertilizer or frequency of cutting on yield and composition of this grass. Watkins and Lewy (*6*)[3] in San Salvador, found that Guinea grass yielded progressively more when cut at 1-, 2-, and 3-month intervals. Rivera-Brenes (*2*) in Puerto Rico, however, reported that Guinea grass yielded more when cut at 40-day intervals than when cut at intervals of 3 and 4 months, and that the lignin content increased while the protein content decreased with length of harvest interval.

Rodríguez (*3*) in Puerto Rico, found that the application of 200 pounds of nitrogen per acre yearly more than doubled the yields of Guinea grass growing in the humid region. Vicente and Figarella (*5*) in Puerto Rico, found that the application of 100 pounds of nitrogen per acre to Guinea grass growing in the semiarid region increased yields by about one-third, while Vicente, *et al.* (*4*), reported that applications of 300 pounds of nitrogen per acre yearly more than doubled the yields of irrigated Guinea grass.

This paper presents the results of an experiment carried out to characterize the response of Guinea grass to nitrogen fertilization as affected by frequency of cutting and season of the year. The effects of treatments on forage composition and on soil acidity were also studied.

## MATERIALS AND METHODS

The experiment was carried out at Río Piedras, over 2 consecutive years. The mean annual temperature is about 76° F., with seasonal variations

[1] This work was carried out cooperatively between the U. S. Department of Agriculture and the Agricultural Experiment Station of the University of Puerto Rico.

[2] Project Supervisor, Physical Science Aid, and Soil Scientist, respectively, Soil and Water Conservation Research Division, Agricultural Research Service, U. S. Department of Agriculture.

[3] Italic numbers in parentheses refer to Literature Cited, p. 239.

of less than 10° F. Rainfall totalled 102.6 and 56.3 inches during the first and second years, respectively, representing close to record deviations from the long-time average of about 80 inches.

The soil is a Fajardo clay, a deep, red, fairly well-drained soil, on about a 20-percent slope. Initially, the surface 6 inches averaged 3.2 percent of

FIG. 1.—Sixty-day-old Guinea grass showing the effects of nitrogen fertilization. Results clockwise from plot at lower left: Nitrogen applied at rates of 0, 200, and 400 pounds per acre yearly in 6 equal applications.

organic matter, 0.17 percent of nitrogen, 12.1 m.e. exchange capacity, and 6.0 m.e. of exchangeable bases per 100 gm. of soil, and had a pH of 4.8.

The treatments used were as follows:

| *Harvest intervals* (*Days*) | *Nitrogen levels* (*Pounds N per acre yearly*) |
|---|---|
| 40 | 0 |
| | 200 |
| 60 | 400 |
| | 800 |
| 90 | 1,600 |

All combinations of these treatments were tested using a split-plot design, with harvest intervals as the main plots and nitrogen levels as the subplots. All treatments were replicated four times. Subplots were

10 x 20 feet, surrounded by ditches to prevent fertilizer from washing into adjoining plots.

The upper 6 inches of soil in all plots was limed to a pH of about 6.5 at the start of the experiment. Blanket additions of phosphorus and potassium were made at the rate of 300 pounds of $P_2O_5$ per acre from 20-percent superphosphate in one application and 600 pounds $K_2O$ from KCl per acre annually in four to nine equal applications, depending on frequency of cutting. The nitrogen was applied as ammonium sulfate in four to nine equal applications yearly, depending on frequency of cutting.

The grass was cut at the prescribed intervals, weighed, and the forage removed from the plots. Samples from each plot at every harvest were analyzed for dry matter and total nitrogen. The crude-protein content was calculated using the factor 6.25 times N. Samples were composited by plots at the end of the first year and analyzed for calcium, phosphorus, potassium, magnesium, and lignin. Yields were taken over three 60-day periods, after terminating the experiment, to determine the residual effects of the treatments.

At the end of the experiment the soil in all plots cut every 60 days and receiving 0, 400, 800, and 1,600 pounds of nitrogen per acre yearly was sampled at 6-inch intervals to a depth of 2 feet and analyzed for pH and exchangeable bases.

## RESULTS

### EFFECT OF LENGTH OF HARVEST INTERVAL

The data in table 1 and figure 2 show that yields increased markedly with length of harvest interval. At the 800-pound level of nitrogen, Guinea grass produced 27,552, 32,733, and 43,608 pounds of dry matter per acre yearly when cut at 40-, 60-, and 90-day intervals, respectively. The dry-matter content of the forage also increased with harvest intervals, averaging 20.2, 23.8, and 30.4 percent for these cutting intervals, respectively.

The protein content of the forage, however, dropped with each increase in harvest interval, averaging at the 800-pound level of nitrogen, 11.1, 9.6, and 7.3 percent when the grass was cut at 40, 60, and 90 days, respectively. Frequency of cutting had little effect on protein yields, however.

The proportion of applied nitrogen recovered in the forage, and the pounds of dry matter produced per pound of fertilizer nitrogen, tended to increase with length of harvest interval.

The data in table 2 show that the phosphorus, calcium, and potassium contents of the forage decreased with length of harvest interval, while the magnesium content showed a similar tendency. The phosphorus content of the forage averaged 0.35, 0.26, and 0.21 percent; the calcium content 0.93, 0.77 and 0.60 percent, and the potassium content 2.00, 1.78, and 0.98

percent, with a 40-, 60-, and 90-day interval respectively. The relatively high calcium content of Guinea grass is worthy of note.

The lignin content of the forage increased with length of harvest interval

TABLE 1.—*The effects of nitrogen fertilization and frequency of cutting on the yield and protein content of Guinea grass and on the efficiency of utilization of the applied nitrogen over a 2-year period*

| Nitrogen applied per acre yearly | Yield of green forage per acre yearly | Yield of dry matter per acre yearly | Crude-protein content | Crude-protein yield per acre yearly | Recovery of N in forage | Dry matter produced per pound of each increment of N |
|---|---|---|---|---|---|---|
| *Grass cut every 40 days* | | | | | | |
| *Lb.* | *Lb.* | *Lb.* | *Percent* | *Lb.* | *Percent* | *Lb.* |
| 0 | 42,302 | 9,227 | 7.8 | 718 | — | — |
| 200 | 70,082 | 15,016 | 8.1 | 1,215 | 39.8 | 28.9 |
| 400 | 113,644 | 23,758 | 9.0 | 2,145 | 57.1 | 43.7 |
| 800 | 141,142 | 27,552 | 11.1 | 3,061 | 46.9 | 9.5 |
| 1,600 | 153,898 | 26,829 | 14.7 | 3,933 | 32.1 | 0 |
| *Grass cut every 60 days* | | | | | | |
| 0 | 42,986 | 10,891 | 6.2 | 679 | — | — |
| 200 | 85,512 | 21,320 | 6.0 | 1,273 | 47.6 | 52.1 |
| 400 | 121,047 | 29,184 | 7.0 | 2,046 | 54.7 | 39.3 |
| 800 | 146,206 | 32,733 | 9.6 | 3,151 | 49.5 | 8.9 |
| 1,600 | 155,774 | 34,374 | 12.4 | 4,253 | 35.7 | 2.1 |
| *Grass cut every 90 days* | | | | | | |
| 0 | 45,380 | 13,195 | 4.9 | 647 | — | — |
| 200 | 98,342 | 31,015 | 5.0 | 1,553 | 72.5 | 89.1 |
| 400 | 115,982 | 36,910 | 5.6 | 2,055 | 56.3 | 29.5 |
| 800 | 143,088 | 43,608 | 7.3 | 3,191 | 51.0 | 16.7 |
| 1,600 | 166,324 | 48,259 | 9.9 | 4,777 | 41.3 | 5.8 |

averaging 7.89, 9.49, and 10.76 percent when the grass was cut every 40, 60, and 90 days, respectively.

Less weeding was required with the longer harvest intervals.

## EFFECT OF NITROGEN FERTILIZATION

The data in table 1 and figure 2 show that yields increased rapidly with nitrogen fertilization up to at least the 400-pound level at all harvest intervals. With a 60-day harvest interval, yields were almost tripled to 29,184 pounds of dry matter per acre yearly by the application of 400 pounds of nitrogen (table 1). A detailed analysis of the data shows that

TABLE 2.—*The effects of nitrogen fertilization and harvest intervals on the mineral and lignin contents of Guinea grass and on withdrawal of nutrients in forage*[1]

| Nitrogen fertilization (pounds N per acre yearly) | Results at harvest intervals indicated | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 40 days | | 60 days | | 90 days | | Average | |
| | Percentage composition[2] | Pounds withdrawn per acre yearly | Percentage composition[2] | Pounds withdrawn per acre yearly | Percentage composition[2] | Pounds withdrawn per acre yearly | Percentage composition[2] | Pounds withdrawn per acre yearly. |
| | | | | *Nitrogen* | | | | |
| 0 | 1.30 | 124.9 | 1.01 | 107.6 | 0.74 | 91.2 | 1.01 | 107.9 |
| 400 | 1.44 | 334.9 | 1.09 | 315.7 | .82 | 294.6 | 1.12 | 315.1 |
| 800 | 1.65 | 453.3 | 1.42 | 500.7 | 1.07 | 471.3 | 1.38 | 475.1 |
| Average | 1.46 | 304.4 | 1.17 | 308.0 | .87 | 285.7 | | |
| | | | | *Phosphorus* | | | | |
| 0 | 0.45 | 43.2 | 0.38 | 40.5 | 0.31 | 38.2 | 0.38 | 40.6 |
| 400 | .37 | 83.5 | .22 | 63.2 | .16 | 57.5 | .25 | 68.2 |
| 800 | .24 | 65.9 | .19 | 70.0 | .15 | 66.1 | .19 | 67.3 |
| Average | 0.35 | 64.2 | 0.26 | 57.9 | 0.21 | 53.9 | | |
| | | | | *Calcium* | | | | |
| 0 | 0.92 | 88.4 | 0.71 | 75.6 | 0.52 | 64.1 | 0.72 | 76.0 |
| 400 | .88 | 198.5 | .78 | 225.9 | .64 | 229.9 | .77 | 218.1 |
| 800 | .98 | 269.2 | .81 | 285.6 | .65 | 286.3 | .81 | 280.4 |
| Average | 0.93 | 185.4 | 0.77 | 195.7 | 0.60 | 193.4 | | |
| | | | | *Potassium* | | | | |
| 0 | 2.00 | 192.2 | 1.56 | 166.1 | 1.17 | 144.1 | 1.58 | 167.5 |
| 400 | 1.80 | 406.1 | 2.08 | 249.3 | .95 | 341.3 | 1.61 | 332.2 |
| 800 | 2.21 | 607.7 | 1.70 | 599.4 | .82 | 361.2 | 1.58 | 522.6 |
| Average | 2.00 | 402.0 | 1.78 | 338.3 | 0.98 | 282.2 | | |
| | | | | *Magnesium* | | | | |
| 0 | 0.40 | 38.4 | 0.32 | 34.1 | 0.35 | 43.1 | 0.36 | 38.6 |
| 400 | .49 | 110.5 | .38 | 110.1 | .33 | 118.6 | .40 | 113.1 |
| 800 | .47 | 129.1 | .48 | 169.2 | .40 | 176.2 | .45 | 158.2 |
| Average | 0.45 | 92.7 | 0.39 | 104.5 | 0.36 | 112.6 | | |
| | | | | *Lignin* | | | | |
| 0 | 7.08 | — | 8.41 | — | 8.97 | — | 8.15 | — |
| 400 | 8.20 | — | 9.43 | — | 11.43 | — | 9.69 | — |
| 800 | 8.38 | — | 10.64 | — | 11.87 | — | 10.30 | — |
| Average | 7.89 | — | 9.49 | — | 10.76 | — | | |

[1] All values are averages of 4 replications composited from all cuttings over a full 1-year period.

[2] On dry-weight basis.

yields increased with nitrogen fertilization up to the 400-pound level even during dry seasons of slow growth. Whenever the weather was favorable, a strong response in yield was evident up to the 800-pound level of nitrogen. Similarly, figure 2 shows that during the very dry year of 1957 the yield curve levelled off at the 400-pound level of nitrogen, whereas a strong response up to the 800-pound level was evident during 1956 when there was abundant rainfall.

The protein content of the forage increased with nitrogen rates up to the highest level tested, averaging when cut every 60 days, 6.2, 7.0, 9.6, and 12.4 percent when fertilized with 0, 400, 800, and 1,600 pounds of nitrogen per acre yearly, respectively. The highest protein content of 14.7

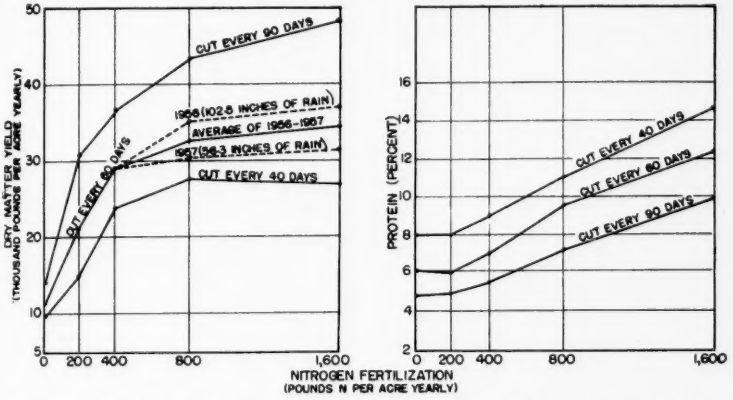
DRY MATTER YIELD (THOUSAND POUNDS PER ACRE YEARLY)
CUT EVERY 90 DAYS
1956 (102.6 INCHES OF RAIN)
AVERAGE OF 1956-1957
1957 (58.3 INCHES OF RAIN)
CUT EVERY 60 DAYS
CUT EVERY 40 DAYS
PROTEIN (PERCENT)
CUT EVERY 40 DAYS
CUT EVERY 60 DAYS
CUT EVERY 90 DAYS
NITROGEN FERTILIZATION (POUNDS N PER ACRE YEARLY)

FIG. 2.—Effects of nitrogen fertilization and frequency of cutting on yield and protein content of Guinea grass.

percent was attained with a 40-day harvest interval and 1,600 pounds of nitrogen per acre yearly. The assumption is made that the nitrogen was essentially all in the amino form since no more than traces of nitrates were found in the forage.

Protein yields increased rapidly with nitrogen fertilization up to the maximum level tested, averaging with a 60-day harvest interval, 679, 2,046, 3,151, and 4,253 pounds per acre yearly at the 0-, 400-, 800-, and 1,600-pound levels of nitrogen, respectively.

The data in table 1 show that, generally, about half of the applied nitrogen was recovered in the forage when 800 pounds or less were applied per acre yearly, with a lower recovery at the 1,600-pound rate. If residual yields are considered, recovery of fertilizer nitrogen would average about 4 percent higher. Guinea grass obtained about 100 pounds of nitrogen from the soil per acre yearly when none was applied as fertilizer.

The efficiency of utilization of fertilizer nitrogen decreased rapidly with increasing rates. With a 60-day harvest interval, 52.1, 39.3, 8.9, and 2.1 pounds of dry matter were produced per pound of each successive increment of nitrogen.

The data in table 2 show that the phosphorus content of the forage decreased with increased nitrogen rates at all harvest intervals, averaging 0.38, 0.25, and 0.19 percent at the 0-, 400-, and 800-pound levels of nitrogen, respectively. Nitrogen rates had no apparent effect on the calcium, potassium, or magnesium contents of the forage. The lignin content of the forage, however, increased significantly with nitrogen rates, averaging with a 60-day harvest interval, 8.41, 9.43, and 10.64 percent at the 0-, 400-, and 800-pound levels, respectively.

Nitrogen fertilization reduced weed growth. Plots cut every 60 days and fertilized with 400 pounds or more of nitrogen per acre yearly required no weeding.

### NUTRIENT WITHDRAWAL AT HIGH YIELD LEVELS

Table 2 shows that intensively managed Guinea grass withdraws large amounts of nutrients, particularly nitrogen and potassium. With a 60-day harvest interval and an 800-pound rate of nitrogen, about 70 pounds of phosphorus, 286 pounds of calcium, 169 pounds of magnesium, and 500 pounds of nitrogen were removed per acre yearly in the forage. About 600 pounds of potassium were also withdrawn, but much of this represented luxury consumption. Recent experiments by the authors indicate that, with optimum fertilization, Guinea grass contains about 1 percent of potassium rather than the 1.7 percent found in the trials under discussion. Thus, about 330 pounds of potassium would have been withdrawn per acre yearly if optimum potassium levels had been used. From the above it is apparent that heavy fertilization is required to sustain high yields.

Nutrient withdrawal increased greatly with nitrogen rates, but was not strongly affected by frequency of cutting. Withdrawal of calcium and potassium was more than tripled, of phosphorus almost doubled, of magnesium about quadrupled, and of nitrogen almost quintupled, when nitrogen rates were raised from 0 to 800 pounds per acre yearly with a 60-day harvest interval.

### RESIDUAL EFFECTS ON YIELDS

Plots harvested at 90-day intervals during the course of the experiment yielded about 30 percent more over a 60-day period ending 6 months after the experiment was terminated, than plots formerly harvested at 40- and 60-day intervals. The differences were more marked at low nitrogen rates.

Higher residual yields were produced by plots receiving heavy nitrogen applications during the course of the experiment. The following tabulation

shows the effect of nitrogen rates used during the course of the experiment on yields and protein content of forage produced over a 60-day period ending 8 months after the last application of nitrogen.

| *Nitrogen level* | *Pounds of dry matter per acre* | *Percentage of protein* |
|---|---|---|
| 0 | 1,040 | 6.7 |
| 200 | 1,350 | 7.3 |
| 400 | 1,400 | 7.4 |
| 800 | 2,300 | 8.4 |
| 1,600 | 3,700 | 13.6 |

## EFFECT OF SEASON OF THE YEAR

Approximately the same yields were produced during the second year when rainfall totalled 56.3 inches as during the first year with a rainfall of 102.6 inches, but seasonal yields varied considerably.

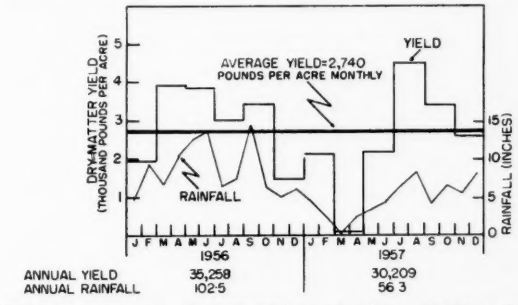


FIG. 3.—Effects of season of the year and of rainfall on yields of Guinea grass cut every 60 days and fertilized with 800 pounds of nitrogen per acre yearly.

Figure 3 shows that season of the year, largely as a result of rainfall, had a marked effect on forage production. November, December, January, and February yields were below average, while July, August, September, and October yields exceeded the average during both years. March, April, May, and June yields were far below average in 1957 as a result of the driest spring on record at Río Piedras.

Protein content of the forage also varied considerably with season of the year, ranging with a 60-day harvest interval and 800 pounds of nitrogen, from as low as 7.4 percent to as high as 11.2 percent. In general, protein content was highest during seasons of low yields and vice versa.

## EFFECT OF HEAVY APPLICATIONS OF AMMONIUM SULFATE ON SOIL REACTION AND BASE STATUS

Heavy applications of ammonium sulfate had a strong effect on soil acidity and base status as shown by the data in table 3. The application of 800 pounds of nitrogen per acre yearly as ammonium sulfate for 2 con-

secutive years, reduced the pH of the upper 6 inches of soil from 6.7 to 4.6 and the exchangeable base content from 11.6 to 6.1 m.e. per 100 gm. of soil. At the 1,600-pound level of nitrogen, the pH was reduced to 4.0 and the exchangeable bases to 2.7 m.e. per 100 gm. of soil. The effect on base status of the soil was apparent to a considerable depth in the profile. There was no indication of an accumulation of bases in the lower horizons of soil. Abruña, Pearson, and Elkins (*1*), have discussed these results in detail. Nitrogen rates had no apparent effect on organic-matter content of the soil.

TABLE 3.—*The effect of nitrogen fertilizer in the form of ammonium sulfate on the reaction and exchangeable-base status at different depths of a Fajardo clay planted to Guinea grass over a 2-year period*[1]

| Depth (inches) | pH for— | | | M.e. exchangeable bases per 100 gm. of soil for— | | |
|---|---|---|---|---|---|---|
| | No N | 800 lb. N per acre yearly | 1,600 lb. N per acre yearly | No nitrogen | 800 lb. N per acre yearly | 1,600 lb. N per acre yearly |
| 0–6 | 6.7 | 4.6 | 4.0 | 11.6 | 6.1 | 2.7 |
| 6–12 | 5.8 | 4.5 | 4.1 | 7.4 | 4.6 | 3.2 |
| 12–18 | 5.0 | 4.8 | 4.2 | 7.4 | 4.9 | 3.6 |
| 18–24 | 4.7 | 4.5 | 4.3 | 5.9 | 4.9 | 3.9 |

[1] All values are averages of 4 replications.

## DISCUSSION

Although highest yields were obtained when Guinea grass was cut every 90 days, the forage was of poor quality as indicated by the high lignin and relatively low protein and mineral contents. On the other hand; quality of the forage cut every 40 days was excellent. It is probably best to harvest Guinea grass every 40 to 60 days, using the shorter interval during seasons of fast growth. Guinea grass pastures may be grazed as often as every 30 days during periods of fast growth.

The application of at least 400 pounds of nitrogen per acre yearly was very profitable under the conditions of this experiment, if the reasoning in the preceding paper on Napier grass is accepted. During seasons of high rainfall and fast growth the application of up to 800 pounds of nitrogen per acre yearly appeared warranted.

With a 60-day harvest interval and 800 pounds of nitrogen per acre yearly, Guinea grass produced about 73 tons of green forage, or 32,733 pounds of dry matter per acre yearly with 9.6 percent of protein. This is sufficient to meet the roughage requirements of about 4½ mature cows or steers.

With proper management, yields of this magnitude can be obtained under widely different soil and climatic conditions found on the Island, provided moisture is adequate. In other experiments by the authors, properly managed Guinea grass yielded 28,482 pounds of dry matter per acre yearly on a steep Catalina clay in the mountain region, and 41,714 pounds of dry matter per acre yearly on a fertile, irrigated soil on the semiarid south coast.

The increase in lignin and decrease in protein and mineral contents of the forage with length of harvest interval is probably a normal result or maturity. The increase in protein content with nitrogen fertilization is to be expected, but the concurrent increase in lignin content is difficult to explain. The decrease in phosphorus content with nitrogen fertilization may have been caused by the dilution effect of higher yields in the presence of a relatively constant, limited amount of available phosphorus in the soil.

The data suggest that variations in forage production throughout the year could be reduced by using a longer harvest interval and heavier nitrogen fertilization during seasons of slow growth and a shorter harvest interval and low nitrogen fertilization during seasons of fast growth. However, applications in excess of a rate equivalent to 800 pounds of nitrogen per acre yearly during dry periods can cause burning and in some cases kill the grass. At high nitrogen rates, care should be taken not to apply the fertilizer directly on the clumps of grass.

The rapid increase in soil acidity resulting from heavy applications of ammonium sulfate indicate the need for annual applications of limestone to prevent loss of bases deep in the profile. The use of nitrogen sources having a lower residual acidity would reduce this loss.

## SUMMARY

The effects of nitrogen rates ranging from 0 to 1,600 pounds of N per acre yearly and of 40-, 60-, and 90-day harvest intervals on the yield and composition of Guinea grass and on soil acidity were determined for 2 consecutive years.

Yields increased with nitrogen fertilization up to the 800-pound level, while protein content and protein yields increased up to the 1,600-pound level. About half of the fertilizer nitrogen was recovered in the forage when 800 pounds or less were applied per acre yearly. Efficiency of utilization, in terms of dry matter produced per pound of nitrogen, decreased with increasing rates. The phosphorus content of the forage decreased while the lignin content increased with nitrogen rates. Fertilization with nitrogen had no apparent effect on the calcium, potassium, or magnesium content of the forage.

Yields and lignin content of the forage increased while the protein,

phosphorus, calcium, magnesium, and potassium contents decreased with length of harvest interval.

A 60-day harvest interval and 400 to 800 pounds of nitrogen per acre yearly, depending on rainfall, seemed to be the optimum combination. With the higher nitrogen rate, Guinea grass yielded 32,733 pounds of dry matter (about 73 tons of green forage) per acre yearly with 9.6 percent of protein. With this treatment Guinea grass removed about 70 pounds of phosphorus, 286 pounds of calcium, 169 pounds of magnesium, 500 pounds of nitrogen, and 330 pounds of potassium per acre yearly.

About the same yields were produced during each of the two years although rainfall varied greatly. Seasonal yields varied widely.

The application of 800 pounds of nitrogen as ammonium sulfate per acre annually over a 2-year period caused a drop of 2.1 pH units and a loss of 5.5 m.e. of exchangeable bases per 100 gm. in the upper 6 inches of soil.

**RESUMEN**

Se estudió el efecto de aplicaciones de nitrógeno que variaban entre 0, y 1,600 libras por cuerda por año y de intervalos de corte de 40, 60, y 90 días, en el rendimiento y composición de la yerba Guinea (*Panicum maximum*), y en la acidez del suelo durante 2 años consecutivos.

Los rendimientos aumentaron con niveles de nitrógeno hasta 800 libras por cuerda por año. El contenido y rendimiento de proteína aumentó con niveles de nitrógeno hasta 1,600 libras por cuerda por año. Se recuperó en el forraje aproximadamente la mitad del nitrógeno aplicado hasta 800 libras por cuerda, pero la eficiencia de utilización expresada en términos de forraje seco producido por cada libra de nitrógeno disminuyó según se aumentaban los niveles de nitrógeno. El contenido de fósforo disminuyó, pero el de lignina aumentó al aumentar los niveles de nitrógeno. El contenido de calcio, potasio, y magnesio en el forraje no se afectó con las aplicaciones de nitrógeno.

Los rendimientos de forraje seco y el contenido de lignina aumentaron al alargarse los intervalos de corte. Sin embargo, el contenido de proteína, fósforo, calcio, magnesio, y potasio disminuyó según se alargaron los intervalos de corte.

Un intervalo de corte de 60 días y de 400 a 800 libras de nitrógeno por cuerda por año dependiendo de la abundancia de lluvia parece ser el tratamiento óptimo con 800 libras de nitrógeno al año, la yerba Guinea produjo 32,738 libras de materia seca (como 73 toneladas de forraje verde) por cuerda por año, con un contenido de proteína de 9.6 por ciento. Con este tratamiento, la yerba extrajo del suelo 500 libras de nitrógeno, 330 libras de potasio, 286 libras de calcio, 169 libras de magnesio, y 70 libras de fósforo por cuerda por año.

El rendimiento no varió apreciablemente durante los 2 años de experimentación, pero la producción varió considerablemente durante distintas épocas del año.

La aplicación de 800 libras de nitrógeno, en forma de sulfato amónico, por cuerda por año durante 2 años, redujo el pH de las 6 pulgadas de superficie en 2.1 unidades y acarreó una pérdida de 5.4 miliquievalentes de bases intercambiables por cada 100 gramos de suelo.

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# Effects of Nitrogen Fertilization and Frequency of Cutting on the Yield and Composition of Para Grass in Puerto Rico[1]

*José Vicente-Chandler, Servando Silva, and Jacinto Figarella*[2]

## INTRODUCTION

Para grass (*Panicum purpurascens*) (fig. 1) is one of the most widely used forage grasses of the humid Tropics, thriving wherever there is abundant rainfall and adequate soil fertility. This grass is adapted both to grazing and cutting and, in Puerto Rico, is usually grown on valuable land where it is essential that high yields be obtained.

Little is known regarding the effects of nitrogen fertilizer or frequency of cutting on yield and composition of this grass. Rivera-Brenes (*1*)[3] in Puerto Rico, reported that Para grass yielded slightly more when cut at 90-day intervals and less when cut at 120-day intervals than when harvested every 40 days, and that the lignin content increased while the protein content decreased with length of harvest interval, while Rodríguez (*2*) found that the application of 200 pounds of nitrogen per acre yearly about doubled the yields of this grass.

This paper presents results of an experiment carried out to characterize the response of Para grass to nitrogen fertilization as affected by frequency of cutting and season of the year. The effects of treatments on forage composition were also studied.

## MATERIALS AND METHODS

The experiment was carried out at Río Piedras over a full year period with a total of 95.1 inches of rainfall. The mean annual temperature is about 76° F., with seasonal variations of less than 10° F.

The soil is a Fajardo clay, a deep, fairly well-drained soil, on about a 20-percent slope. Initially, the surface 6 inches averaged 3.2 percent of organic matter, 0.17 percent of nitrogen, 12.1 m.e. exchange capacity, and 6.0 m.e. of exchangeable bases per 100 gm. of soil, and had a pH 4.8. The treatments used were as follows:

[1] This work was carried out cooperatively between the U. S. Department of Agriculture and the Agricultural Experiment Station of the University of Puerto Rico.

[2] Project Supervisor, Physical Science Aid, and Soil Scientist, respectively, Soil and Water Conservation Research Division, Agricultural Research Service, U. S. Department of Agriculture.

[3] Italic numbers in parentheses refer to Literature Cited, p. 248.

| *Harvest intervals (Days)* | *Nitrogen levels (Pounds N per acre yearly)* |
|---|---|
| 40 | 0 |
| | 200 |
| 60 | 400 |
| | 800 |
| 90 | 1,600 |

All combinations of these treatments were tested using a split-plot design with harvest intervals as the main plots and nitrogen levels as the

FIG. 1.—Para grass fifty days after cutting showing response to nitrogen fertilization. Plot in foreground received 200 pounds of nitrogen per acre yearly while that in background received 800 pounds.

subplots. All treatments were replicated four times. Subplots were 10 x 20 feet surrounded by ditches to prevent fertilizer from washing into adjoining plots.

The upper 6 inches of soil in all plots was limed to a pH of about 6.5 at the start of the experiment. Blanket additions of phosphorus and potassium were made at the rate of 300 pounds $P_2O_5$ per acre from 20-percent superphosphate in one application and 600 pounds $K_2O$ from KCl per acre annually in four to nine equal applications, depending on frequency of cutting. The nitrogen was applied as ammonium sulfate in four to nine equal applications yearly, depending on frequency of cutting.

The grass was cut at the prescribed intervals, weighed, and the forage removed from the plots. Samples from each plot at every harvest were analyzed for dry matter and total nitrogen. The crude-protein content was calculated using the factor 6.25 times N. Samples were composited

TABLE 1.—*The effects of nitrogen fertilization and frequency of cutting on the yield and protein content of Para grass and on the efficiency of utilization of the applied nitrogen over a 1-year period*

| Nitrogen applied per acre yearly | Yield of green forage per acre yearly | Yield of dry matter per acre yearly | Crude-protein content | Crude-protein yield per acre yearly | Recovery of N in forage | Dry matter produced per pound of each increment of N |
|---|---|---|---|---|---|---|
| | | | *Grass cut every 40 days* | | | |
| *Lb.* | *Lb.* | *Lb.* | *Percent* | *Lb.* | *Percent* | *Lb.* |
| 0 | 22,523 | 5,156 | 7.3 | 378 | — | — |
| 200 | 54,758 | 11,624 | 8.1 | 943 | 45.2 | 32.3 |
| 400 | 83,066 | 17,109 | 9.2 | 1,576 | 47.7 | 27.4 |
| 800 | 120,117 | 23,607 | 11.7 | 2,759 | 47.6 | 16.2 |
| 1,600 | 133,094 | 25,444 | 15.0 | 3,807 | 34.3 | 2.3 |
| | | | *Grass cut every 60 days* | | | |
| 0 | 31,919 | 7,805 | 6.4 | 498 | — | — |
| 200 | 74,223 | 17,616 | 6.3 | 1,115 | 49.5 | 49.1 |
| 400 | 101,574 | 23,832 | 7.2 | 1,716 | 48.8 | 31.1 |
| 800 | 139,635 | 30,841 | 9.5 | 2,937 | 47.8 | 17.5 |
| 1,600 | 157,635 | 32,579 | 12.1 | 3,949 | 34.5 | 2.2 |
| | | | *Grass cut every 90 days* | | | |
| 0 | 42,468 | 13,070 | 4.8 | 626 | — | — |
| 200 | 76,181 | 22,734 | 4.3 | 987 | 29.0 | 48.3 |
| 400 | 104,673 | 32,919 | 4.8 | 1,592 | 38.7 | 50.9 |
| 800 | 128,598 | 36,294 | 7.2 | 2,615 | 39.8 | 8.4 |
| 1,600 | 143,442 | 39,189 | 8.9 | 3,471 | 28.4 | 3.6 |

by plots at the end of the year and analyzed for calcium, phosphorus, potassium, magnesium, and lignin.

## RESULTS

### EFFECT OF LENGTH OF HARVEST INTERVAL

The data in table 1 and figure 2 show that yields increased markedly with length of harvest interval. At the 800-pound level of nitrogen, Para grass produced 23,607, 30,841, and 36,294 pounds of dry matter per acre

yearly when cut at 40-, 60-, and 90-day intervals, respectively. The dry-matter content of the forage also increased with the harvest interval averaging 20.7, 22.9, and 29.5 percent, with the 40-, 60-, and 90-day harvest intervals, respectively.

The protein content of the forage, however, dropped with each increase in harvest interval, averaging at the 800-pound level of nitrogen, 11.7, 9.5, and 7.2 percent when the grass was cut every 40, 60, and 90 days, respectively. Frequency of cutting had little effect on protein yields, however.

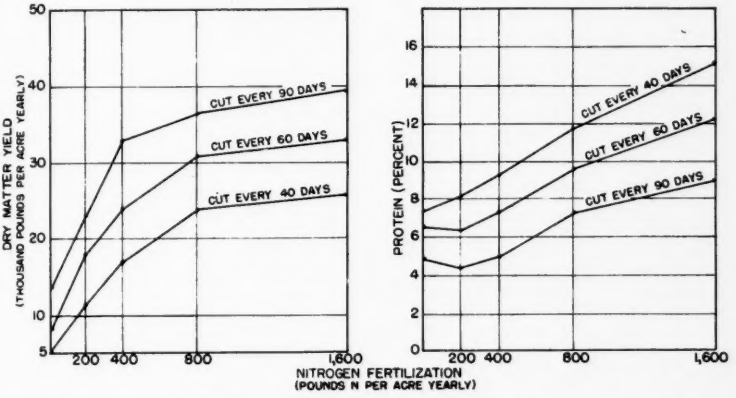


FIG. 2.—Effects of nitrogen fertilization and frequency of cutting on yield and protein content of Para grass.

A lower proportion of the applied nitrogen was recovered in the forage when the grass was cut every 90 days than with the shorter harvest intervals.

The data in table 2 show that the phosphorus, calcium, potassium, and magnesium contents of the forage decreased significantly while lignin content increased with length of harvest interval.

## EFFECT OF NITROGEN FERTILIZATION

The data in table 1 and figure 2 show that yields increased rapidly with nitrogen fertilization up to the 800-pound level (fig. 1). With a 60-day harvest interval, yields were about quadrupled, attaining 30,841 pounds of dry matter per acre yearly, by the application of 800 pounds of nitrogen. A detailed analysis of the data shows that yields increased with nitrogen fertilization up to the 400-pound level, even during dry seasons of slow growth. Whenever weather was favorable, a strong response in yield was

evident up to the 800-pound level of nitrogen. When nitrogen at the rate of 800 pounds per acre yearly was applied during dry weather, considerable burning and loss of stand was evident. This effect was very serious at the 1,600-pound level of nitrogen.

The protein content of the forage increased with nitrogen rates up to the highest level tested, averaging when cut every 60 days, 6.4, 7.2, 9.5, and 12.1 when fertilized with 0, 400, 800, and 1,600 pounds of nitrogen per acre yearly, respectively. Forage containing 15 percent of protein was obtained when Para grass was cut every 40 days and fertilized with 1,600 pounds of nitrogen per acre yearly. The assumption is made that the nitrogen was essentially all in amino form since no more than traces of nitrates were found in the forage.

Protein yields increased rapidly with nitrogen fertilization up to the maximum level tested, averaging with a 60-day harvest interval, 498, 1,716, 2,937, and 3,949 pounds per acre yearly, at the 0-, 400-, 800-, and 1,600-pound levels of nitrogen, respectively.

The data in table 1 show that, with a 60-day harvest interval, about half of the applied nitrogen was recovered in the forage when 800 pounds or less were applied per acre yearly, compared to about 35 percent at the 1,600-pound rate. Para grass obtained about 80 pounds of nitrogen from the soil when none was applied as fertilizer.

The efficiency of utilization of fertilizer nitrogen decreased rapidly with increasing rates. With a 60-day harvest interval, 49.1, 31.1, 17.5, and 2.2 pounds of dry matter were produced per pound of each successive increment of nitrogen.

The data in table 2 show that the phosphorus content of the forage decreased significantly with increased nitrogen fertilization, averaging 0.27, 0.20, and 0.17 percent at the 0-, 400-, and 800-pound levels of nitrogen, respectively. Nitrogen fertilization had no strong effect on the calcium, potassium, or magnesium contents of the forage. The lignin content of the forage, however, increased with nitrogen rates averaging 7.77, 8.44, and 9.02 percent at the 0-, 400-, and 800-pound rates of nitrogen.

Proper fertilization with nitrogen helped reduce weeds.

### NUTRIENT WITHDRAWAL AT HIGH YIELD LEVELS

Table 2 shows that intensively managed Para grass withdraws large amounts of nutrients, particularly nitrogen and potassium. With a 60-day harvest interval and an 800-pound rate of nitrogen, about 52 pounds of phosphorus, 120 pounds of calcium, 77 pounds of magnesium, 469 pounds of nitrogen, and 524 pounds of potassium were removed per acre yearly in the forage. It follows that heavy fertilization is required to sustain high yields.

Nutrient withdrawal increased greatly with nitrogen rates but was not

TABLE 2.—*The effects of nitrogen fertilization and harvest interval on the mineral and lignin contents of Para grass and on withdrawal of nutrients in forage*

| Nitrogen fertilization (pounds N per acre yearly) | Results at harvest intervals indicated | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 40 days | | 60 days | | 90 days | | Average | |
| | Percentage composition[2] | Pounds withdrawn per acre yearly | Percentage composition[2] | Pounds withdrawn per acre yearly | Percentage composition[2] | Pounds withdrawn per acre yearly | Percentage composition[2] | Pounds withdrawn per acre yearly |
| | | | | *Nitrogen* | | | | |
| 0 | 1.17 | 60.3 | 1.02 | 79.6 | 0.77 | 100.6 | 0.98 | 80.2 |
| 400 | 1.47 | 251.5 | 1.15 | 274.1 | .77 | 253.5 | 1.13 | 259.7 |
| 800 | 1.87 | 441.5 | 1.52 | 468.8 | 1.15 | 417.4 | 1.51 | 442.5 |
| Average | 1.50 | 251.1 | 1.23 | 274.2 | 0.89 | 257.2 | | |
| | | | | *Phosphorus* | | | | |
| 0 | 0.30 | 15.5 | 0.28 | 21.8 | 0.23 | 30.1 | 0.27 | 22.5 |
| 400 | .25 | 42.8 | .21 | 50.1 | .15 | 49.4 | .20 | 47.4 |
| 800 | .19 | 44.8 | .17 | 52.4 | .14 | 50.8 | .17 | 49.4 |
| Average | 0.25 | 34.4 | 0.22 | 41.4 | 0.17 | 43.4 | | |
| | | | | *Calcium* | | | | |
| 0 | 0.37 | 19.1 | 0.29 | 22.6 | 0.26 | 34.0 | 0.31 | 45.7 |
| 400 | .39 | 66.7 | .35 | 83.4 | .29 | 95.5 | .34 | 81.9 |
| 800 | .44 | 103.8 | .39 | 120.3 | .34 | 123.4 | .39 | 115.8 |
| Average | 0.40 | 63.2 | 0.34 | 75.4 | 0.30 | 84.3 | | |
| | | | | *Potassium* | | | | |
| 0 | 1.77 | 91.3 | 1.64 | 128.0 | 1.12 | 146.4 | 1.51 | 121.9 |
| 400 | 2.21 | 378.1 | 1.75 | 417.1 | 1.00 | 329.2 | 1.65 | 274.8 |
| 800 | 1.84 | 434.4 | 1.70 | 524.3 | 1.40 | 508.1 | 1.64 | 448.9 |
| Average | 1.94 | 301.2 | 1.70 | 356.5 | 1.17 | 327.9 | | |
| | | | | *Magnesium* | | | | |
| 0 | 0.26 | 13.4 | 0.16 | 12.5 | 0.11 | 14.4 | 0.18 | 13.4 |
| 400 | .27 | 46.2 | .20 | 47.7 | .15 | 49.4 | .21 | 47.7 |
| 800 | .34 | 80.3 | .25 | 77.1 | .23 | 83.5 | .27 | 80.3 |
| Average | 0.29 | 46.6 | 0.20 | 45.8 | 0.16 | 49.1 | | |
| | | | | *Lignin* | | | | |
| 0 | 7.49 | — | 7.42 | — | 8.40 | — | 7.77 | — |
| 400 | 7.53 | — | 8.41 | — | 9.39 | — | 8.44 | — |
| 800 | 8.22 | — | 8.95 | — | 9.88 | — | 9.02 | — |
| Average | 7.75 | — | 9.26 | — | 9.22 | — | — | — |

[1] All values are averages of 4 replicates composited from all cuttings over a full 1-year period.

[2] On dry-weight basis.

strongly affected by frequency of cutting. Withdrawal of phosphorus was about doubled, of calcium about quintupled, of potassium about quadrupled, of magnesium about sextupled, and of nitrogen about quintupled when nitrogen rates were raised from 0 to 800 pounds per acre yearly with a 60-day harvest interval.

### EFFECT OF SEASON OF THE YEAR

Figure 3 shows that season of the year, largely as a result of rainfall, had a marked effect on forage production with maximum variations approximating 100 percent. Above-average yields were produced in May, June, July, and August, while low yields were produced during November, December, January, and February.

Protein content of the forage also varied markedly with season of the year ranging, with a 60-day harvest interval and 800 pounds of nitrogen,

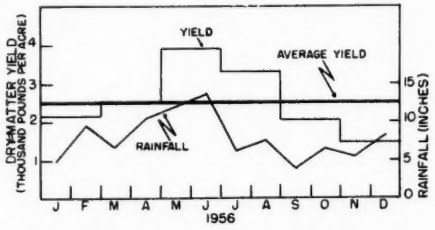


FIG. 3.—Effects of season of the year and rainfall on yield of Para grass cut every 60 days and fertilized with 800 pounds of nitrogen per acre yearly.

from as low as 7.4 to as high as 12.8 percent. In general, protein content was highest during seasons of low yields and vice versa.

## DISCUSSION

Although highest yields were obtained when Para grass was cut every 90 days, the forage was of poor quality as indicated by the high lignin and relatively low protein and mineral contents. On the other hand, quality of the forage cut every 40 days was excellent. It is probably best to cut Para grass every 40 to 60 days, using the shorter interval during periods of fast growth.

The application of up to 800 pounds of nitrogen per acre yearly was profitable under the conditions of this experiment where rainfall was abundant, if the reasoning in the paper on Napier grass (first paper in this issue) is accepted. During dry years, the response to nitrogen fertilization will probably level off at about the 400-pound rate and higher rates should not be used during severe droughts, in order to avoid serious burning.

With a 60-day harvest interval and 800 pounds of nitrogen per acre yearly, Para grass produced 30,841 pounds of dry forage, or about 70 tons of green forage, with 9.5 percent of protein. This is sufficient to meet the roughage requirements of about four mature cows or steers. It is of interest to note that similarly treated Para grass yielded 26,308 pounds of dry matter per acre yearly in still-unpublished experiments conducted by the authors on a steep Catalina clay in the mountain region.

The increase in lignin and decrease in protein and mineral contents with length of harvest interval is probably a normal result of maturity. The increase in protein content with nitrogen rates is to be expected, but the similar increase in lignin content is hard to explain. The decrease in phosphorus content with increasing nitrogen rates may have been caused by the dilution effect of higher yields in the presence of a relatively constant, limited amount of available phosphorus in the soil.

Rainfall was the main factor affecting seasonal growth of Para grass, although other factors such as day length and temperature were also apparently involved. The data suggest that seasonal variations in forage production could be reduced by using a longer harvest interval and heavier nitrogen fertilization during seasons of slow growth and a shorter harvest interval and lower nitrogen fertilization during seasons of fast growth. However, applications in excess of a rate equivalent to 400 pounds of nitrogen per acre yearly during dry periods can cause severe burning and loss of stand.

## SUMMARY

The effects of rates ranging from 0 to 1,600 pounds of nitrogen per acre yearly and of 40-, 60-, and 90-day harvest intervals on the yield and composition of Para grass were determined over a 1 year period.

Yields increased with nitrogen fertilization up to the 800-pound level, while protein content and protein yields increased up to the 1,600-pound level.

About half of the fertilizer nitrogen was recovered in the forage when 800 pounds or less were applied per acre. Efficiency of utilization in terms of dry matter produced per pound of nitrogen, decreased rapidly with increasing rates.

The phosphorus content of the forage decreased while the lignin content increased with nitrogen rates. Nitrogen fertilization had no pronounced effect on the calcium, potassium, or magnesium contents of the forage.

Yields and lignin content of the forage increased while protein, phosphorus, calcium, magnesium, and potassium contents decreased with length of harvest interval.

There are marked seasonal variations in yield due primarily to rainfall.

With a 60-day harvest interval and 800 pounds of nitrogen per acre yearly, Para grass yielded 30,841 pounds of dry forage, or about 70 tons of green forage, with a 9.5-percent protein content. With this treatment Para grass removed 52.4 pounds of P, 120 of Ca, 524 of K, 77 of Mg, and 469 pounds of N per acre yearly. It is not advisable to use rates of more than 400 pounds of nitrogen per acre per year during dry weather.

**RESUMEN**

Se estudió el efecto de aplicaciones de nitrógeno que variaban entre 0 y 1,600 libras por cuerda por año, y de intervalos de corte de 40, 60, y 90 días, en el rendimiento y composición de la yerba Pará (*Panicum purpurascens*).

Los rendimientos aumentaron con niveles de nitrógeno hasta 800 libras por cuerda por año. El contenido y rendimiento de proteína aumentó con niveles de nitrógeno hasta 1,600 libras por cuerda por año. Se recuperó en el forraje aproximadamente la mitad del nitrógeno aplicado hasta 800 libras por cuerda, pero la eficiencia de utilización expresada en términos de forraje seco producido por cada libra de nitrógeno disminuyó según se aumentaban los niveles de nitrógeno. El contenido de fósforo disminuyó, pero el de lignina aumentó al aumentar los niveles de nitrógeno. El contenido de calcio, potasio, y magnesio en el forraje no se afectó con las aplicaciones de nitrógeno.

Los rendimientos de forraje seco y el contenido de lignina aumentaron al alargarse los intervalos de corte. Sin embargo, el contenido de proteína, fósforo, calcio, magnesio, y potasio disminuyó segun se alargaron los intervalos de corte.

La producción varió considerablemente durante distintas épocas del año.

Con un intervalo de corte de 60 días y 800 libras de nitrógeno por cuerda por año la yerba Pará produjo 30,841 libras de materia seca (como 70 toneladas de forraje verde) por cuerda por año, con un contenido de proteína de 9.5 por ciento. Con este tratamiento, la yerba extrajo 469 libras de nitrógeno, 524 libras de potassio, 120 libras de calcio, 77 libras de magnesio, y 52.4 libras de fósforo por cuerda por año. No debe aplicarse nitrógeno en más de 400 libras por acre al año en tiempo de sequía.

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# Palatability Trials on Merker grass (*Pennisetum purpureum*), Venezuela grass (*Paspalum fasciculatum*), and Plantain Pseudostalks (*Musa paradisiaca*)

*L. Rivera-Brenes, J. Herencia, J. A. Arroyo, and J. I. Cabrera*[1]

## INTRODUCTION

Merker grass is the most important soilage grass actually grown in Puerto Rico. Besides its high yield per acre, from 70 to 100 tons, its high palatability is well known to all farmers.

Venezuela grass was introduced from Venezuela, South America, to this Station several years ago; that accounts for its name (*2*)[2]. In Venezuela this grass is known as of Chiguirera grass (*5*, *6*) and is a pest in the low wet lands due to its aggressiveness and poor palatability. Cattle eat some of it when it is young and tender, but as soon as it matures they reject it (*5*). A similar situation was observed at Río Piedras (*6*) and, because of this, it was decided to perform palatability trials before making any recommendation.

Plantain pseudostalks are known to be eaten by cattle, but they are not usually used as forage. Around 29,000 acres were planted to plantains and bananas in 1956–57 (*1*). It is a common practice in Puerto Rico to cut and throw away the stalks after the fruit bunches are harvested. These stalks weigh around 40 pounds each on the average, and there are 600 plants to the acre. Production per acre is estimated thus as being about 12 tons; a total of 348,000 tons production is estimated for the whole Island.

Prolonged dry periods are not uncommon in Puerto Rico. During the year 1955–56 the Island suffered nearly 8 months of drought, and many head of cattle died from hunger. The economic losses due to reductions in weight were incalculable. Every year the northern section of Puerto Rico suffers a 30- to 60-day dry period and the south and southwest is dry from 60 to 120 days.

Unfortunately, most of the cattle owners do not practice any forage preservation by making hay or silage during the time of luxurious growth of the grass in the summer and, when the dry period arrives, they give cattle whatever they can find: cane tops, tree leaves, etc.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 254.

Observations on the palatability of Venezuela and Pangola grasses were reported by Rivera-Brenes (*6*). Further palatability trials on these grasses and on plantain pseudostalks were made and are reported in this paper.

## PROCEDURE

The experiment consisted of three trials using a 3 x 3 latin-square design with a 7-day prefeeding period and a 7-day collection period (*2*). Four animals were used per group.

The first experiment was run during July and August 1957; Merker and Venezuela grasses were compared. In the second experiment during July and August 1958, Merker grass, Venezuela grass, and plantain pseudostalks were compared, and in the third experiment during November and December 1958, Merker and Venezuela grasses were compared again.

The grasses were cut at ages between 40 and 60 days, when very green and tender. They were both fertilized with 400 pounds of ammonium sulfate. The plantain pseudostalks were gathered from one of the Substation farms after the bunches were harvested. They were over a year old.

During the second trial the Merker grass plots did not produce enough roughage to finish the experiment and grass of more or less the same age and condition from a nearby field was utilized to finish it. No difference was observed.

The grasses were chopped in a silage chopper each morning. The plantain pseudostalks were chopped in small pieces by hand with a machete. Samples were taken for the determination of moisture content and calculation of dry-matter intake. Digestability determinations were also made. They will be reported separately.

Dry cows and 2-year-old heifers were used, open or less than 5 months pregnant. They were weighed every morning during the collection periods. Total consumption was measured every day. Forages were offered to the animals in three or four servings during the day. At night they were put out in an exercise lot where they had access only to water. Both fresh-material and dry-matter consumption were calculated per 100 pounds of live weight for uniformity.

The percentage of leaves and stem was determined for Venezuela grass. A total of 11 samples was taken during the three trials. Each sample consisted of from 8 to 15 culms as they were cut in the field to be fed. Leaves, with leaf-sheaths attached were separated from the stems and both parts were weighed separately. Chemical analyses were made according to official methods.

## RESULTS AND DISCUSSION

Average consumption of fresh forage and dry-matter per 100 pounds of live weight is presented in table 1. The average chemical analyses for crude protein and dry matter are given in table 2.

Merker grass, besides being much higher in protein content than Venezuela grass, is also higher in dry-matter content. Plantain pseudostalks were very low in both protein and dry-matter content.

Venezuela grass had a leaf-to-stem ratio of 48.57 to 51.43 percent, respectively. In this respect it is similar to Merker grass (*7*).

Although no study was made as to how each of these forages maintained the weight of the animals, it was observed from the daily weights that the cows on Merker grass did not lose weight, those on Venezuela grass lost weight, and those on plantain pseudostalks lost some weight, but not as much as those on Venezuela grass. However, those on Venezuela grass and

TABLE 1.—*Pounds of fresh forage and dry matter consumed per 100 pounds of live weight for the 3 trials, all animals included*

| Merker grass | | Venezuela grass | | Plantain pseudostalks[1] | |
|---|---|---|---|---|---|
| Fresh forage | Dry matter | Fresh forage | Dry matter | Fresh forage | Dry matter |
| 10.02 | 2.00 | 3.93 | 0.69 | 14.93 | 0.80 |

[1] 1 trial.

TABLE 2.—*Crude-protein and dry-matter contents (percent) of the grasses and plantain pseudostalks, average of all trials*

| Forage | Crude protein | Dry matter |
|---|---|---|
| Venezuela grass | 7.07 | 19.16 |
| Merker grass | 11.17 | 21.16 |
| Plantain pseudostalks | 4.52 | 5.87 |

plantain pseudostalks gained in weight after they were changed to Merker grass.

The statistical analysis of the consumption data is presented in table 3. Merker grass was more platable than Venezuela grass. The difference was highly significant.

It is to be noted in the second trial that the cows consumed more plantain pseudostalks than Merker grass; the difference was significant as to green matter consumed, but when dry matter was computed, it was less so. There is no doubt though that plantain pseudostalks are very palatable and that they can properly be used to feed cows in cases of emergency.

Venezuela grass is poor in palatability. This has been observed in its country of origin. When this grass is young, the animals eat some, but not too much, as demonstrated by this experiment.

It was also observed that when this Venezuela grass was chopped all the cut edges became reddish in color, as if they were oxidized. The chopped

material also smelled like linseed oil which is probably the cause of its repellent bad taste. A chemical analysis revealed that this grass contains 0.02 percent of an unknown essential oil or oils.

Expressing the differences found on a percentage basis and taking Merker grass consumption as 100 percent, the consumption of Venezuela grass was 39 percent and that of plantain pseudostalks 149 percent, on a wet basis.

TABLE 3.—*Statistical analysis of the results on palatability as pounds of green roughage and dry matter consumed per 100 lb. of liveweight*

| Forage | Green forage[1] | Dry matter[1] | Green forage L.S.D. | | L.S.D. for dry matter | |
|---|---|---|---|---|---|---|
| Merker grass | 11.79 | 2.35 | (0.01) | (0.05) | (0.01) | (0.05) |
| Venezuela grass | 5.29 | 1.03 | | | | |
| Difference | 6.50** | 1.32** | 1.45 | 1.04 | .35 | .25 |
| Plantain pseudostalks | 14.93 | 0.80 | | | | |
| Merker grass | 9.53 | 1.86 | | | | |
| Difference | 5.40* | 1.06** | 5.49 | 2.39 | .99 | .43 |
| Plantain pseudostalks | 14.93 | 0.80 | | | | |
| Venezuela grass | 2.90 | .36 | | | | |
| Difference | 12.03** | 0.44* | | | | |
| Merker grass | 9.53 | 1.86 | | | | |
| Venezuela grass | 2.90 | .36 | | | | |
| Difference | 6.63** | 1.50** | 5.49 | 2.39 | 1.34 | .59 |
| Merker grass | 9.20 | 1.95 | | | | |
| Venezuela grass | 3.61 | .70 | | | | |
| Difference | 5.59** | 1.25** | 1.46 | 1.05 | .19 | .14 |

[1] ** indicates significance at 1-percent level; * at 5 percent.

Figure 1 presents graphicaly the dry-matter consumption by a 900-pound cow of Merker grass, Venezuela grass, and plantain pseudostalks.

According to Morrison standards (*3*) a 900-pound cow needs from 6.4 to 7.2 pounds of T.D.N. for maintenance. Assuming 50-percent T.D.N. for the dry matter consumed in the forages under test, Merker grass produced almost 2 pounds of T.D.N. over Morrison's high limit. Venezuela grass was short by 2.8 pounds from the low limit, and plantain pseudostalks were short by 3.3 pounds from the low limit.

## SUMMARY AND CONCLUSIONS

Venezuela grass (*Paspalum fassiculatum*) was introduced to Puerto Rico some years ago from Venezuela, South America. Poor palatability was observed as well as its aggressiveness on the low wet lands in the Experiment Station Farm.

Several thousand acres are planted to bananas and plantains (*Musa paradisiaca*) in the Island. The pseudostalks are known to be eaten by cattle, but almost all of them are thrown away after the banana bunches are harvested.

Merker grass (*Pennisetum purpureum*) is the standard soilage grass used and it is very palatable.

Three palatability trials were run to test Venezuela grass, plantain pseudostalks, and Merker grass as a check.

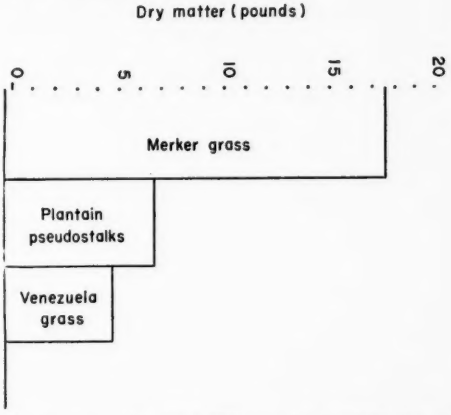


FIG. 1.—Dry-matter consumption by a 900-pound cow of Merker grass, Venezuela grass, and plantain pseudostalks.

Taking the consumption of Merker grass as 100 percent, wet basis, the consumption of Venezuela grass was 39 and that of plantain pseudostalks 149 percent. The differences were statistically significant on both the wet and dry bases.

Plantain pseudostalks contain very little dry matter and should be used only in emergencies.

In the Island we have pasture grasses with recognized good palatability like Pangola, Guinea, Para, Molasses, and others. In any pasture-improvement program on the farm any one of these is preferable to Venezuela grass.

## RESUMEN

La yerba Venezolana, (*Paspalum fassiculatum*) se introdujo a Puerto Rico de Venezuela, Sur América. Se había observado que esta yerba no era

muy apetecida por el ganado y se sabía también de su crecimiento muy agresivo en los terrenos llanos y pantanosos de la finca de la Estación Experimental Agrícola de la Universidad de Puerto Rico, en Río Piedras.

En Puerto Rico se siembran miles de cuerdas de plátanos y guineos. Se sabe que el ganado se come algunos tallos, pero casi todos estos se botan luego de cosechados los racimos.

La yerba Merker es la yerba principal para corte en la Isla. El ganado la apetece mucho.

Se llevaron a cabo tres experimentos para determinar la aceptación que tenía el ganado por la yerba Venezolana antes de hacer otras evaluaciones y para ver la utilidad que se le podría dar a los tallos de las plantas de plátano como forraje. Se usó la yerba Merker como testigo para las comparaciones.

Cuando se tomó el consumo de la yerba Merker a un porcentaje de 100, el consumo de la yerba Venezolana llegó a un 39 por ciento y el de los tallos de plátano a un 149 por ciento. Las diferencias en consumo, tanto para el material fresco como a base de materia seca, fueron altamente significativas.

Los seudo-tallos de plátano contienen muy poca materia seca y se recomienda su uso solamente en casos de emergencia.

En la Isla hay un número de yerbas apetecidas por el ganado, tales como la Pangola, la Guinea, el Malojillo, la Melao y otras. En cualquier programa de mejoramiento de pastos en la finca debe preferirse una de éstas a la Venezolana.

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# Fertility Status of Organic Soils in Puerto Rico[1]

*Julián Roldán*[2]

## INTRODUCTION

### FORMATION OF ORGANIC SOILS

The nature of the formation of organic soils is quite different from that of mineral soils. These very peculiar soils are formed when partly decomposed plant material accumulates in water or in water-saturated soils. The exclusion of air is a factor of outstanding importance in the process. The reducing conditions encountered favor anaerobic micro-organisms. These are capable of breaking down only a few of the organic complexes in plant materials, leaving the remaining plant constituents to accumulate in the form of relatively unavailable carbon and nitrogen compounds of peat (*3*)[3]. Under anaerobic conditions, sugars, amino acids, starches, certain hemicelluloses, and proteins are rapidly decomposed. Celluloses, oils, certain fats, and certain hemicelluloses are decomposed more slowly. The rapidity of decomposition is controlled to some extent by the amount of available nitrogen and minerals (*29*).

The major processes of peat formation are paludification of dry land and filling processes (*29*). These major soil-making processes may lead to either impoverished or enriched peat soils. Accordingly, peat soils have been classified as oligotrophic, eutrophic, or mesotrophic, meaning rich, poor, or intermediate in terms of lime and mineral-element content. These soils are further distinguished by a sequence of layers. The chemical composition of a definite layer depends primarily upon four factors (*31*):

1. Watershed.
2. Nature of the plant remains which have contributed to the formation of the layer.
3. Environmental conditions that predominated during the time of the formation of the layer.

[1] Part of a thesis submitted to the Faculty of the Graduate School of Cornell University, Ithaca, N. Y., in partial fulfillment of the requirements for the degree of Master of Science.

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[3] Italic numbers in parentheses refer to Literature Cited, pp. 266–7.

4. Extent and nature of the processes of decomposition of the plant residues in the particular layer.

These layers show either progressive or regressive development. Progressive development is shown by bogs that have always developed from a wet toward a drier state. Regressive development is illustrated by a change from a relatively dry to a wetter state (*4*).

Whenever the degree of decomposition of the plant material is such that it cannot be identified, the soil is called a muck. All organic soil-surface layers eventually reach this stage of decomposition. Decomposition of peat into muck can be ascertained by making a paste with the soil and sodium pyrophosphate. In pyrophosphate the humic acids go into solution and in doing so indicate that decomposition is under way. This type of decomposition is characteristic of partly drained organic soils.

Some plant communities forming organic soils include plants capable of precipitating calcium, *e.g.*, submerged plants. This may lead to the formation of a layer of calcium carbonate mixed with organic matter, marl. Besides this layer, profiles may also include layers of sedimentary peat, *e.g.*, gyttja, fibrous peat, and fibrous moss peat.

There are different plant associations that give rise to different peats. Duckweed, pondweed, green algae, and blue-green algae form sedimentary peat by supra-aquatic filling. Reeds, sedges, and cattails lead to fibrous peat formation by infra-aquatic filling. Sphagnum moss, labrador tea, tamarack, and black spruce form fibrous peat.

The rate of peat formation has been evaluated from pollen-grain curves and radio-carbon data. The values found are: $0.0021 \pm 0.0006$ and $0.0021 \pm 0.0013$ foot/year, respectively.

## SUBSIDENCE

Whenever organic soils are drained, a reduction in depth of the soil will be observed; this is termed "subsidence." Lowering of the water table makes possible a better aeration of the soil and, as a result, the rate of decomposition is increased.

Laboratory studies indicate that the rate of decomposition depends on the type of peat, which, in turn, is determined by the climatological conditions under which the peat was formed (*14*). The greatest decomposition of the soil will take place with temperatures over 75° F. and with moisture contents between 50 and 75 percent by volume for a soil containing 90 percent of water at saturation (*11*).

It has been observed that when a virgin peat or muck is brought into use, the rate of subsidence is rapid at first, but decreases with time. The rate appears to be proportional to the depth to water table. Data published by the University of Florida Agricultural Experiment Station in relation to

the subsidence rate in the Everglades show that the relation between the depth to water table and subsidence is as follows (*10*):

| *Average depth of water table* (*Feet*) | *Average annual subsidence* (*Feet/year*) |
|---|---|
| 1.0 | 0.03 |
| 1.5 | .06 |
| 2.0 | .08 |
| 2.5 | .11 |
| 3.0 | .14 |

Subsidence may occur as a result of compaction and shrinkage. Shrinkage is especially noticeable after the land is first drained. When planning the reclamation of peat lands the rate of subsidence should be considered since it will limit the period of years during which the land may be cultivated profitably. Investigational work in the Everglades carried on by Neller (*15*) has shown that maintenance of the water table at as high a level as possible provides the only means of conserving the soil from subsidence.

## WATER TABLE

The depth to the water table in an organic soil is important. As has already been pointed out, subsidence is proportional to depth to the water table and, to minimize subsidence, the water table should be maintained as high as other considerations will permit. For crop production the water table should be high enough to supply sufficient water for optimum growth, and it should be low enough to prevent crop growth from being retarded by poor soil drainage. The ratio of water-table rise to rainfall is approximately 6 in organic soils[4]. The permeability of some organic soil layers to water is relatively low. The depth to the water table should accommodate all regularly occurring rains without crop damage due to poor drainage. Stoutmire (*24*) found that with a water table 3.5 feet below surface, plants suffered from lack of moisture. At 1 foot plants suffered from too much moisture, and at 2 feet he found the best environment.

The importance of controlling depth to the water table has been shown by Ellis and Morris (*6*) when they found that there was a negative correlation between a test for ferrous iron and the yield of crops. By means of this test they were able to determine the regions of the soil in which aeration took place.

## CHEMICAL PROPERTIES OF ORGANIC SOILS

Many other factors besides subsidence and water table have to be taken into consideration whenever muck soils are put into production. Unlike mineral soils, where the parent material determines fertility status, organic

[4] Personal communication given by Dr. J. E. Dawson to the author.

soils depend on the bog-plant associations from which they were derived for their fertility status. Anyway, both organic and mineral soils can exhibit deficiency or toxicity of elements. It is of general knowledge that most virgin peat soils are of low fertility level, particularly with respect to phosphorus and potassium.

Neller (*16*) has pointed out that the protein in molasses from sugarcane grown on Everglades organic soils is higher than when the cane is grown on mineral soils. This makes the molasses much more valuable for feed.

Staker (*22*), working on some New York peat soils, considered that the presence of exchangeable zinc may be a cause of toxicity in these soils. Moreover, he found that a wide zinc-to-sulfide ratio was associated with poor growth of crops. A narrow ratio was correlated with fair to good growth. As zinc sulfide is insoluble in water he concluded that most of the toxicity prevalent in the soils under study was caused by other forms of zinc. Other studies at the Belle Glades Experiment Station (*26*) have shown that, on alkaline organic soils, considerable quantities of zinc are held as the humate and carbonate.

Neller (*17*) studying low- and high-lime peats, found that in high-lime peats the conditions were optimum for nitrification and that the conversion of the nitrogenous material of the peat was rapid. There was no indication that pasture grass, corn, or sugarcane would respond to a nitrogenous fertilizer, except for brief periods following a succession of heavy rains.

In an attempt to identify lime-deficient peats Nygard (*18*) reached the conclusion that acidity values without lime determinations can be utilized to recognize many peat soils not deficient in lime. He further found that lime-deficient peats from uncultivated bogs contained less than 0.63 percent of CaO in the dry peat and 0.74 percent in the ash-free dry matter. As a further clue he emphasized that Azotobacter is more numerous in lime-sufficient peats.

Allaway (*1*) investigated the availability of replaceable calcium from different types of colloids as affected by degree of calcium saturation. Of the five colloids investigated, peat was the one that gave the highest replaceability.

Copper-deficiency symptoms have been observed in crops grown on peat soils. Sugarcane growing on saw-grass peat soils has been observed with marked copper-deficiency symptoms. A tremendous response has been observed when the soil is treated with copper salts (*27*). Forsee, *et al.* (*7*), in an experiment using copper oxide as a source of copper for plants, indicated that finely ground copper oxide is as efficient as copper sulfate. Harmer (*9*), working with several crops on organic soils, showed that a considerable response to copper is obtained if the soil pH is around 6.0 or below. The lower the pH the greater the number of crops which are likely

to show a response. It has been observed by the author that the amount of response to copper shown by a given crop may vary from year to year and from one part of a growing season to another. Generally more response was obtained in a hot dry period than in a cool wet period.

Lucas (*12*), studying minor-element deficiencies and responses in plant growth on organic soils, suggested that copper is less available in limed mucks than in slightly acid mucks. During his studies he found that the addition of copper reduced slightly both the zinc and manganese absorption by plants. It seemed to him that plants deficient in copper absorb excessive amounts of manganese because of a physiological unbalance of the elements.

Organic soils show progressively decreasing amounts of available manganese as their pH values increase. Beyond pH 6.0 they may not have the ability to supply the plant requirements either from residual or applied manganese (*8*). If the pH is lowered, manganese solubility is increased and deficiency of this element prevented.

In a study of the effects of various soil treatments on improving an unproductive muck soil, Comin (*2*) obtained large increases in celery yields through sterilization of the soil.

Dawson (*5*) recommended that caution be observed in liming peat soils. At high pH values the application of lime usually caused a manganese deficiency on sensitive crops. He stated that the presence of free calcium carbonate whatever the source, might also cause manganese deficiency.

Townsend and Wedgworth (*25*) observed symptoms of yellowing and death of plants which were attributed to manganese deficiency. The trouble was associated with soils having a high content of marl. This deficiency was best prevented by adding both manganese and sulfur to the soil. Quastel, *et al.* (*20*) associated manganese deficiency with soils high in organic matter and lime status, and having a pH value between 6.5 and 8.0. He stated that applications of manganous sulfate to deficient soils are often ineffective because of the extremely rapid oxidation of the manganous ions and consequent fixation in an unavailable form, probably as manganese dioxide. The conclusion he reached is that the concentration of available manganese in the soil is a function of the kinetics of a number of reactions in what he terms the manganese cycle. Thus, to him, an increase in manganous ions can be accomplished as:

1. A direct result of reducing agents.
2. Using specific poisons.
3. Stimulation of manganese-reducing organisms relative to the oxidizing organisms.

In studies with sugarcane (*28*) upon areas where the soils were alkaline

from burning, treatment with sulfur or sulfuric acid either with or without manganese has shown unusual benefits.

## EXPERIMENTATION

### ORGANIC SOILS IN PUERTO RICO

Organic soils in general have not been widely studied in Puerto Rico. Their chemical properties have not been studied yet, nor have their potentialities for use in agriculture received adequate study. Although there is a program for the reclamation of these lands the complexity of the problem *per se* is not only one of reclamation, but also of knowing the chemical properties of these soils and the problems likely to arise after their reclamation. That these soils can be rendered very productive is not to be doubted, but a knowledge of the intricacies of their management is of paramount importance. Every place in the world in which these soils have been used in agriculture, the users have had to deal with a wide variety of problems; to mention a few: Water table, weeds, toxicity, subsidence, and so forth, have presented a challenge to any one working with them.

In Puerto Rico there are more than 28,000 acres of organic soils, much of which can be used for crop production. Much of this land, if utilized properly, would greatly benefit the economy of the Island.

The distribution of organic soils in Puerto Rico (*13*) is as follows:

| *Soil series* | *Soil group* | *Acres* |
|---|---|---|
| Tiburones muck | Bog | 6,848 |
| Saladar muck | do. | 8,000 |
| Saladar muck, shallow phase | Half-bog | 1,152 |
| Peat | Bog | 7,360 |
| Peat, shallow phase | Half-bog | 1,280 |
| Reparada | do. | 2,560 |
| Ursula | do. | 1,088 |
| Total | | 28,180 |

### SAMPLING AND DESCRIPTION OF SAMPLES

Twenty-five soil samples of the Caño Tiburones area were taken for analyses. The samples were taken at two depths, 0–8 and 8–24 inches. The typical vegetation growing in the area where the samples were taken consisted mostly of pasture, natural pasture, or pasture and brush, except in three places where sugarcane was growing.

The type of soils consisted mostly of Tiburones muck, Saladar muck, or peat. A description of these soils taken from the Soil Survey of Puerto Rico (*22*) follows:

*Tiburones Muck*

Areas of Tiburones muck, if not drained and cultivated, are covered with water most of the year. The most noticeable types of vegetation are ferns, sedges, grass,

and cat-tails. When dry, drained, and cultivated, the surface soil to a depth of 10 inches is nearly black granular loose mealy more or less mineralized slightly acid friable muck, but when wet it is black plastic sticky muck. This layer is underlain by black stringy fibrous tule peat consisting of partly decomposed stems and fibers. It is slightly acid in reaction and salty. Here and there throughout this material, however, there is a band of somewhat blue or green plastic smooth clay about 6 or 8 inches thick, which is acid and slightly salty. Below the clay are other layers of tule peat.

*Saladar Muck*

Most areas of Saladar much are covered with water most of the time and support growing or cut-over mangrove forests. This type of muck consists of dark grayish-brown or black smooth salty strongly acid silty clay material and partly decomposed organic matter in which there is a mass of living and dead plant roots. In places there is a black slimy ooze covering the surface to a depth of 2 or 3 inches. At a depth of about 10 inches is brown smooth-textured organic matter containing layers of raw or partly decayed plant remains. In places the material from the surface down is black or very dark grayish-brown smooth fine-textured silt interspersed with plant remains in various stages of decomposition. Nearly all areas where this soil is present contain harmful quantities of salt brought in by the tide.

*Saladar Muck, Shallow Phase*

The shallow phase of Saladar muck represents a condition rather than a consistent development of a soil profile. It is always very wet, usually under water and generally contains considerable salt. In places it may be composed mostly of peat and muck, with some mineral soil, and in other places it may be mostly mineral soil, and in other places it may be mostly mineral soil with some 12 inches thick underlain by white acid sand.

*Peat*

Most of the peat areas are in mangrove swamps. Peat in general has a reddish brown coarsely fibrous surface material about 10 inches thick. In mangrove thickets it contains many somewhat yellow fine rootlets of mangroves, and in most places the top-most inch or two of the surface layer is black sticky tidal ooze. Below the surface layer is fine-fibered brown peat, which generally continues below a depth of four feet and rests on grayish-black or bluish-black plastic stickly clay containing many gray fine rootlets. Peat is acid in all layers and very salty unless drained.

### ANALYSES OF SAMPLES

Samples were air-dried and ground in a mortar after which they were passed through a 2-mm. sieve. Analyses of the samples were done following the rapid microchemical soil tests as outlined by Peech and English (*19*). (See table 4 for the analytical results.)

## INTERPRETATION OF RESULTS

Averages of the soil-test data for the three types of organic soils under study are presented in table 1. The data indicate that Tiburones muck is better supplied with nutrients than either Saladar muck or peat. Soluble salts, iron, aluminum, and manganese are present in the least amounts in

the peat-soil type; this seems to be favorable from the standpoint of crop production.

### PHOSPHORUS AND POTASSIUM

As expected from a virgin peat soil results indicate a low level of fertility as far as available phosphorus and potassium are concerned. Phosphorus values are especially of such low level in the three soil types that application of phosphate fertilizer seems necessary.

The potassium level is higher in the Tiburones muck-soil type and lower in the peat soil type. The Saladar muck is of an intermediate level in respect to available potassium. The area sampled in general shows a need for an application of potassium fertilizer if the growing of crops is going to be undertaken successfully.

TABLE 1.—*Average soil-test data for 3 types of organic soils from Puerto Rico*[1]

| Soil type | Depth (inches) | P | $NO_3$ N | $NH_3$ N | K | Mn | Fe | Al | Soluble salts EC $\times 10^3$ |
|---|---|---|---|---|---|---|---|---|---|
| Tiburones muck | 0–8 | 4 | 52 | 102 | 387 | 90 | 278 | 79 | 11.75 |
| Do. | 8–24 | 4 | 31 | 102 | 414 | 94 | 259 | 81 | 17.65 |
| Saladar muck | 0–8 | 1 | 25 | 100 | 150 | 90 | 95 | 115 | 10.50 |
| Do. | 8–24 | 1 | 18 | 170 | 140 | 115 | 200 | 160 | 19.00 |
| Peat | 0–8 | 5 | 50 | 60 | 95 | 50 | 2 | 5 | 6.80 |
| Do. | 8–24 | 1 | 5 | 70 | 30 | 35 | 13 | 40 | 14.00 |

[1] *Results expressed in pounds of constituent per 2,000,000 pounds of soil.*

### MANGANESE

Manganese content is definitely lower in the peat-soil type than in either Tiburones muck or Saladar muck. No significant correlation was found between manganese values by soil test at 0–8 inches or 8–24 inches depth and pH values. Evidence of a probable manganese deficiency is seen, especially in spots where the pH of the soil is above 6.0 and the presence of free calcium carbonate has been detected.

### IRON AND ALUMINUM

Iron values by soil test are higher in Tiburones muck. Saladar muck ranks intermediate in iron values and the peat-soil type has the lowest iron values.

Saladar muck has the highest content of aluminum by soil test, followed by Tiburones muck and peat.

Both iron and aluminum values by soil test show a highly significant negative correlation with soil pH values. In the case of iron the correlation coefficient was $-0.716$ and in the case of aluminum $-0.920$.

In general, it can be said that the iron and aluminum values obtained

indicate that toxicity of these elements will be a problem to deal with in the area studied. In the area where the pH was lower than 6.0 the iron and aluminum values obtained are often high enough to render the growth of crops unsatisfactory.

TABLE 2.—*Conductivity values of soil samples expressed in millimhos/cm.*

| Sample No. | EC × $10^3$ (millimhos/cm.) at 0–8 in. | EC × $10^3$ (millimhos/cm.) at 8–24 in. |
|---|---|---|
| 1 | 10.5 | 7.6 |
| 2 | 9.2 | 14.5 |
| 3 | 7.6 | 8.5 |
| 4 | 6.8 | 14.0 |
| 7 | 3.5 | 5.5 |
| 10 | 5.6 | 11.5 |
| 15 | 10.0 | 17.0 |
| 17 | 2.5 | 4.9 |
| 18 | 2.8 | 5.8 |
| 19 | 8.0 | 13.0 |
| 21 | 7.2 | 14.0 |
| 23 | 10.5 | 19.0 |
| 24 | 12.5 | 19.0 |
| 26 | 2.5 | 12.0 |
| 27 | 11.5 | 18.0 |
| 29 | 4.4 | 18.0 |
| 32 | 13.0 | 20.0 |
| 33 | 5.2 | 5.6 |
| 37 | 22.0 | 38.0 |
| 38 | 21.0 | 22.0 |
| 41 | 15.5 | 33.0 |
| 43 | 40.0 | 40.0 |
| 45 | 27.0 | 40.0 |
| 47 | 14.0 | 28.0 |
| 50 | 4.8 | 10.0 |

## SOLUBLE SALTS

Because of the proximity of the area to the sea and for reasons described in discussing the origin and formation of Caño Tiburones, the author believes that a high salt content would be expected on certain spots of the area sampled.

A rough estimate of the salinity status of the area is presented. For convenience and also for reasons of comparison the soluble-salt content expressed in K × $10^5$ units are converted to EC × $10^3$ units. This unit is a practical conductivity unit for most soil-salinity work.

Table 2 shows the conductivity values obtained by analysis expressed in millimhos/centimeter.

Table 3 is an appraisal of the salinity problem in the area under study.

The values of the conductivity scale as given by Richards *et al.* (*21*) have been multiplied by two because a more realistic view is given thus of the salinity problem under field conditions. Table 3 indicates that salinity would not be a problem if due precautions were taken in soil management practices.

The analysis of the samples procured for the soil tests is given in table 4.

## SUMMARY AND CONCLUSIONS

A general literature review on formation, subsidence, water table, and chemical properties of organic soils has been presented and discussed. Soil samples from a virgin peat soil of Puerto Rico were analyzed by rapid microchemical soil tests and, from them, the general fertility level of the

TABLE 3.—*Appraisal of the salinity problem in the area under study*

| Scale of conductivity (millimhos/cm. at 25° C.) | Salinity effects | Percentage of samples from 0–8 in. | Percentage of samples from 8–24 in. |
|---|---|---|---|
| 0 | Salinity effects mostly negligible | 12 | 0 |
| 4 | Yields of very sensitive crops may be restricted | 32 | 20 |
| 8 | Yields of many crops restricted | 40 | 32 |
| 16 | Only tolerant crops yield satisfactorily | 12 | 32 |
| 32 | Only a few very tolerant crops yield satisfactorily | 4 | 16 |

area sampled was evaluated. The relation of the different soil types to the soil-test data has been presented.

From the preceding investigation the following conclusions were drawn:

1. The virgin peat soils from Puerto Rico are low in phosphorus and potassium.

2. No significant correlation was found between manganese values by soil test and soil pH values.

3. A probable manganese deficiency is seen in spots where the pH of the soils is above 6.0, and the presence of free calcium carbonate has been detected.

4. A highly significant negative correlation was found for iron values by soil test and soil pH values.

5. A highly significant negative correlation was found for aluminum values by soil test and soil pH values.

6. In areas where the pH was lower than 6.0 the iron and aluminum values obtained are often high enough to render growth of crops unsatisfactory.

TABLE 4.—*Analysis of samples—results of soil tests*

| Sample No. | Depth of sample | pH | Pounds per acre ($2 \times 10^6$ lb. of soil) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | P | $NO_3$ N | $NH_3$ N | K | Mn | Fe | Al | $CaCO_3$ | Soluble salts K $\times 10^5$ |
| 1 | 0–8″ | 5.75 | 2.5 | 60 | 85 | 270 | 160 | 190 | 120 | + | 1,050 |
| | 8–24″ | 5.80 | 2 | 10 | 110 | 320 | 75 | 100 | 55 | +++ | 760 |
| 2 | 0–8″ | 7.55 | 6 | 40 | 100 | 160 | 300 | 4 | 5 | ++++ | 920 |
| | 8–24″ | 7.35 | 4 | 10 | 100 | 150 | 400 | 35 | 5 | ++++ | 1,450 |
| 3 | 0–8″ | 5.90 | 1 | 10 | 75 | 170 | 100 | 80 | 95 | +++ | 760 |
| | 8–24″ | 5.75 | 1 | 5 | 50 | 115 | 40 | 65 | 90 | – | 850 |
| 4 | 0–8″ | 7.25 | 5 | 50 | 60 | 95 | 50 | 2 | 5 | ++++ | 680 |
| | 8–24″ | 5.85 | 1 | 5 | 70 | 30 | 35 | 13 | 40 | – | 1,400 |
| 7 | 0–8″ | 7.55 | 8 | 30 | 75 | 130 | 90 | 5 | 5 | ++++ | 350 |
| | 8–24″ | 6.55 | 5 | 5 | 60 | 100 | 5 | 1 | 10 | ++ | 550 |
| 10 | 0–8″ | 6.80 | 2 | 50 | 60 | 170 | 50 | 7 | 10 | ++++ | 560 |
| | 8–24″ | 5.25 | 1 | 5 | 60 | 65 | 5 | 30 | 70 | – | 1,150 |
| 15 | 0–8″ | 5.35 | 1 | 10 | 65 | 85 | 45 | 130 | 95 | + | 1,000 |
| | 8–24″ | 5.40 | 1 | 5 | 75 | 95 | 45 | 40 | 50 | – | 1,700 |
| 17 | 0–8″ | 7.25 | 4 | 85 | 60 | 230 | 10 | 2 | 5 | ++++ | 250 |
| | 8–24″ | 6.20 | 1 | 5 | 75 | 55 | 8 | 3 | 10 | + | 490 |
| 18 | 0–8″ | 7.40 | 20 | 80 | 50 | 85 | 5 | 1 | 5 | +++ | 280 |
| | 8–24″ | 7.15 | 16 | 45 | 50 | 65 | 5 | 1 | 5 | +++ | 580 |
| 19 | 0–8″ | 7.35 | 3 | 85 | 75 | 210 | 70 | 1 | 5 | ++++ | 800 |
| | 8–24″ | 7.00 | 1 | 20 | 60 | 50 | 110 | 1 | 5 | – | 1,300 |
| 21 | 0–8″ | 4.85 | 1 | 60 | 105 | 250 | 5 | 80 | 100 | – | 720 |
| | 8–24″ | 4.25 | 1 | 20 | 150 | 150 | 8 | 220 | 190 | – | 1,400 |
| 23 | 0–8″ | 5.25 | 1 | 25 | 100 | 150 | 90 | 95 | 115 | – | 1,050 |
| | 8–24″ | 4.35 | 1 | 18 | 170 | 140 | 115 | 200 | 160 | – | 1,900 |
| 24 | 0–8″ | 5.15 | 2 | 45 | 110 | 440 | 120 | 55 | 80 | – | 1,250 |
| | 8–24″ | 3.75 | 1 | 50 | 225 | 190 | 210 | 800 | 165 | – | 1,900 |
| 26 | 0–8″ | 6.05 | 2 | 10 | 65 | 170 | 55 | 7 | 45 | + | 1,250 |
| | 8–24″ | 5.60 | 1 | 5 | 75 | 130 | 55 | 20 | 80 | – | 1,200 |
| 27 | 0–8″ | 6.95 | 7 | 200 | 90 | 740 | 50 | 3 | 5 | ++++ | 1,150 |
| | 8–24″ | 6.95 | 3 | 250 | 50 | 360 | 65 | 18 | 5 | ++++ | 1,800 |
| 29 | 0–8″ | 6.45 | 1 | 5 | 55 | 220 | 85 | 1 | 35 | ++ | 440 |
| | 8–24″ | 6.05 | 1 | 8 | 75 | 145 | 60 | 7 | 45 | – | 1,800 |
| 32 | 0–8″ | 7.35 | 10 | 20 | 100 | 120 | 220 | 3 | 5 | ++++ | 1,300 |
| | 8–24″ | 6.35 | 20 | 5 | 55 | 145 | 30 | 1 | 5 | – | 2,000 |
| 33 | 0–8″ | 7.65 | 6 | 30 | 95 | 95 | 260 | 40 | 5 | ++++ | 520 |
| | 8–24″ | 7.75 | 3 | 35 | 110 | 65 | 350 | 85 | 5 | ++++ | 560 |
| 37 | 0–8″ | 4.15 | 2 | 25 | 115 | 530 | 130 | 250 | 120 | – | 2,200 |
| | 8–24″ | 3.35 | 3 | 45 | 220 | 740 | 110 | 1,000 | 200 | – | 3,800 |
| 38 | 0–8″ | 3.85 | 1 | 20 | 80 | 525 | 85 | 240 | 110 | – | 2,100 |
| | 8–24″ | 6.25 | 9 | 5 | 100 | 415 | 200 | 45 | 35 | ++++ | 2,200 |
| 41 | 0–8″ | 4.45 | 3 | 70 | 80 | 650 | 40 | 1,100 | 255 | – | 1,550 |
| | 8–24″ | 4.10 | 2 | 15 | 100 | 680 | 90 | 200 | 175 | – | 3,300 |
| 43 | 0–8″ | 3.80 | 4 | 50 | 270 | 1,680 | 5 | 1,000 | 190 | – | 4,000 |
| | 8–24″ | 4.90 | 4 | 5 | 60 | 2,945 | 5 | 2 | 35 | – | 4,000 |
| 45 | 0–8″ | 3.50 | 3 | 90 | 350 | 755 | 40 | 1,200 | 190 | – | 2,700 |
| | 8–24″ | 4.35 | 1 | 5 | 240 | 1,470 | 25 | 85 | 115 | – | 4,000 |
| 47 | 0–8″ | 3.45 | 3 | 65 | 100 | 870 | 30 | 1,100 | 135 | – | 1,400 |
| | 8–24″ | 2.95 | 2.5 | 65 | 100 | 870 | 110 | 1,100 | 225 | – | 2,800 |
| 50 | 0–8″ | 4.40 | 3 | 50 | 75 | 345 | 120 | 900 | 200 | – | 480 |
| | 8–24″ | 3.30 | 4 | 85 | 140 | 195 | 150 | 2,100 | 275 | – | 1,000 |

7. Salinity is not a problem in the area studied if correct soil-management practices are used.

## RESUMEN Y CONCLUSIONES

Se ha presentado un repaso de la literatura en relación a la formación, descenso, nivel freático y propiedades químicas de los suelos orgánicos.

Fué evaluado el nivel de fertilidad de un suelo turboso virgen de Puerto Rico. Como resultado de esta investigación se ha llegado a las siguientes conclusiones:

1. Los suelos turbosos vírgenes de Puerto Rico son bajos en fósforo y potasio.

2. No se encontró una correlación significativa entre los valores de manganeso obtenidos por análisis del suelo y la acidez de los suelos turbosos.

3. Una probable deficiencia de manganeso se prevee en los sitios donde hay carbonato de cal libre y el pH del suelo es sobre 6.0.

4. Una alta y significativa correlación negativa fué encontrada entre los valores de hierro obtenidos por análisis del suelo y la acidez de los suelos turbosos.

5. Una alta y significativa correlación negativa fué encontrada entre los valores de aluminio obtenidos por análisis del suelo y la acidez de los suelos turbosos.

6. En los sitios donde los valores de hierro y aluminio obtenidos son altos y donde el pH del suelo es menor de 6.0, el crecimiento de las cosechas, probablemente, estará limitado por estos factores.

7. La salinidad no es un problema en el área estudiada, si se usan las prácticas correctas para el manejo de los suelos.

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# Evaluation of the Effects of Organic Matter and Other Soil Characteristics Upon the Aggregate Stability of Some Tropical Soils[1]

*M. A. Lugo-López and J. Juárez, Jr.*[2]

## INTRODUCTION

The degree of stability of soil aggregates is one of the most important soil characteristics because of its bearing on utilization and conservation. It is particularly important in irrigated soils where highly stable aggregates, other conditions being favorable, allow water to penetrate quickly into the soil; unstable aggregates disperse upon immersion, clog the soil voids, and consequently drainage problems are likely to develop.

The degree of stability is influenced by the presence of binding substances produced through the activity of soil organic matter, and by the physical attractions of clay and fine silt particles themselves. In other areas of the world some relationships have been worked out to determine the degree of influence of organic matter and clay upon aggregate stability. However, no such relationships have been worked out for soils of tropical regions.

This paper reports on studies conducted with soils from the newly developed irrigated area in the Lajas Valley in southwestern Puerto Rico in an attempt to evaluate the stability of soil aggregates in terms of the organic-matter, clay, or silt content of the soils.

## SOILS AND METHODS

### SOILS STUDIED

In this study 23 soil profiles from the Lajas Valley irrigation development project were included. They comprised the major soils of the area. The soils studied include soils of the Aguirre, Guánica, Santa Isabel, Fraternidad, Fe, and Jácana series (*3*)[3]. These soils are generally very deep with a strikingly high, almost uniform clay content of the expanding-lattice type, predominantly small pores, very slow hydraulic conductivity in the subsoil, very low aggregate stability below the surface layer, but with a topsoil of about 1 foot, in some cases almost 2 feet, that conducts

[1] Joint contribution from the Gurabo Substation and the Department of Soils.

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[3] Italic numbers in parentheses refer to Literature Cited, p. 272.

water rather well. They are relatively low in organic matter and nitrogen, and generally high in soluble salts and exchangeable sodium, which increases with depth.

### SAMPLING

The sampling was done as a part of a more extensive study on the nature and properties of the major soils of the Lajas Valley (*3*). Pits 4 feet wide, 4 feet long, and 6 feet deep were dug at 23 selected, scattered, and distant places concentrated mainly at the eastern and central sections of the Valley. Bulk samples were taken from each visually differentiated horizon.

### ANALYTICAL METHODS

Aggregate stability was determined by the method of Bryant, Bendixen, and Slater (*1*) and organic matter by the chromic acid-reduction method.

TABLE 1.—*Summary of the statistical analyses to determine the influence of organic matter, clay, and silt upon soil aggregates stability*

| Independent variable | Number of pairs of observations | Correlation coefficient |
|---|---|---|
| Organic matter | 129 | 0.395[1] |
| Clay | 127 | .030 |
| Silt | 127 | .022 |

[1] Highly significant.

Particle-size distribution was made by the standard pipette method. Simple regression studies were conducted where aggregate stability was considered the dependent variable and organic matter, clay content, or silt content were the independent variables. Coefficients of correlation and determination were calculated in each case.

## RESULTS AND DISCUSSION

Table 1 summarizes the results of the statistical studies conducted to determine the respective influence of organic-matter, clay, and silt contents upon soil-aggregate stability. No significant correlation was obtained when clay content or silt content was considered as the independent variable. A highly significant correlation was obtained between aggregate stability and organic-matter content where a total of 129 pairs of observations were considered. However, only 16 percent of the variability on the measured aggregate stability could be explained on a basis of the organic-matter content of the soils.

Estimates of the percentage of water-stable aggregates can be made

by using a linear regression as a first approximation by means of the equation:

$$Y = a + bX,$$

TABLE 2.—*Comparison of measured aggregate-stability values and values calculated on a basis of the organic-matter content of soils, in percentage*

| Organic-matter content | Measured-aggregate stability | Calculated-aggregate stability[1] | Deviation |
|---|---|---|---|
| 10.9 | 43.5 | 48.4 | 4.9 |
| 2.8 | 17.7 | 17.8 | .1 |
| 1.9 | 19.4 | 14.5 | −4.9 |
| 1.4 | 11.2 | 12.6 | 1.4 |
| .6 | 9.6 | 9.6 | 0 |
| 5.0 | 25.7 | 26.2 | .5 |
| 3.9 | 24.0 | 22.0 | −2.0 |
| .2 | 6.7 | 8.1 | 1.4 |
| 1.4 | 15.5 | 12.6 | −2.9 |
| .3 | 8.1 | 8.5 | .4 |
| 1.7 | 18.9 | 13.8 | −5.1 |
| 1.0 | 13.8 | 11.1 | −2.7 |
| 2.8 | 17.6 | 17.9 | .3 |
| 1.1 | 11.7 | 11.5 | −.2 |
| .8 | 6.0 | 10.3 | 4.3 |
| 2.3 | 12.2 | 16.0 | 3.8 |
| .9 | 9.3 | 10.7 | 1.4 |
| .6 | 7.0 | 9.6 | 2.6 |
| .8 | 9.3 | 10.3 | 1.0 |
| .5 | 7.0 | 9.2 | 2.2 |
| .4 | 12.0 | 8.8 | −3.2 |
| 1.2 | 12.4 | 11.6 | −.8 |
| 3.1 | 22.2 | 19.0 | −3.2 |
| 2.2 | 9.2 | 8.3 | −.9 |

[1] Calculated from the equation: $Y = 7.33 + 3{,}77X$, where $Y$ is the estimated aggregate stability and $X$ is the measured organic-matter content of the soils.

where

$Y$ = percentage aggregate stability to be estimated,
$a$ = constant calculated on basis of the mean aggregate stability, mean organic-matter content, and the regression coefficient,
$b$ = regression coefficient, and
$X$ = mean organic-matter content.

Table 2 shows a comparison of some of the measured aggregate-stability values and those estimated on basis of the organic-matter content of the

soils. The deviations of the estimated from the measured values range between −5.1- to 4.9-percent water-stable aggregates.

It must be kept in mind, however, that the usefulness of the equation developed is seriously limited because of the rather low percentage of the variability in aggregate stability that can be explained on basis of organic-matter content.

Pérez-Escolar (*4*) in his studies to determine the nature of aggregation in latosols found that the destruction of organic matter with hydrogen peroxide caused considerable dispersion of the soil aggregates. Table 3, adapted from Pérez-Escolar (*4*), shows that the clay percentage measured by the pipette method was almost twice as large in treated soils as in soils not treated with hydrogen peroxide. The high stability of aggregates in latosols have been attributed (*2*) to the interrelationship between soil organic matter and iron oxides.

TABLE 3.—*Percentage of clay particles in aggregates of three sizes (millimeters) as affected by hydrogen peroxide treatment*[1]

| Aggregate size | Percentage of clay in indicated treatment | |
|---|---|---|
| | Untreated soil | Soil treated with $H_2O$ |
| 5–3 | 33.8 | 60.0 |
| 3–2 | 32.3 | 61.7 |
| 2–1 | 33.7 | 61.0 |

[1] Adapted from Pérez-Escolar (*4*).

Thus, it can be stated that organic matter is probably the most important single agent determining aggregate stability in soils. Although the percentage of variability in aggregate stability that can be explained on the basis of organic-matter content is not high, it is the only single factor among those studied which could account for any variability at all, the correlation being highly significant.

## SUMMARY

This paper reports on statistical studies conducted to evaluate the degree of stability of soil aggregates in terms of the respective organic-matter, clay, and silt contents of selected soils from the Lajas Valley irrigation development project. Simple regression analyses revealed that there was no correlation between aggregate stability and clay or silt content. However, a highly significant correlation was obtained when organic-matter content was considered as the independent variable. In spite of the level of significance only 16 percent of the variability in aggregate stability can

be explained on a basis of the soil organic-matter content, thus limiting the possible usefulness of estimates made by using the equation developed.


## RESUMEN

Se informan aquí los resultados de estudios estadísticos realizados con la intención de evaluar el grado de estabilidad de los agregados o unidades estructurales de un número seleccionado de suelos del Valle de Lajas en términos de los contenidos de materia orgánica, arcilla o limo. Los análisis de regresión sencilla revelaron que no hay correlación entre la estabilidad de los agregados y el contenido de arcilla o limo. Sin embargo, cuando el contenido de materia orgánica se consideró como la variable independiente se encontró una correlación altamente significativa. A pesar del alto nivel de correlación, solamente es posible explicar un 16 por ciento de la variación en estabilidad de los agregados a base del contenido de materia orgánica. Esto limita considerablemente la utilidad posible de hacer estimados por medio de la ecuación matemática desarrollada.


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# Hydraulic Conductivity of Subsoils of Lajas Valley[1]

*M. A. Lugo-López and R. Pérez-Escolar*[2]

## INTRODUCTION

Hydraulic conductivity of subsoils is considered to be one of the most important soil characteristics. It must be considered in the design of irrigation and drainage systems (*1*)[3] and of soil and water conservation structures (*4*). Furthermore, it is used as one of the key factors in soil classification surveys. Essentially, it is a measure of water movement through a column of soil.

Hydraulic conductivity is one of the most difficult soil factors to evaluate quantitatively (*1*). It is extremely difficult for soil surveyors in fieldwork to estimate upon inspection the hydraulic conductivity of subsoils, one of the required properties for characterizing soils. This paper reports hydraulic-conductivity data for the major soil series of Lajas Valley, an area in southwestern Puerto Rico where an irrigation-drainage development project is under construction. The purpose is to present data that might serve as a guide for soil surveyors in estimating hydraulic values for the soils included in the study. For this purpose replicated measurements were made in an attempt to determine the range of values that might characterize each of the major soils of the Valley.

## THE SOILS STUDIED

In this study 23 profiles from Lajas Valley were included comprising the major soils of the area. Soils of the Aguirre, Guánica, Santa Isabel, San Antón, Fraternidad, Fe, and Jácana series were studied (*3*). These soils are generally very deep with a strikingly high, almost uniform clay content of the expanding-lattice type, predominantly small pores, very low aggregate stability below the surface layer, very slow hydraulic conductivity in the subsoil, but with a topsoil of 1 or 2 feet that conducts water rather well. They are relatively low in organic matter and nitrogen, and generally high in soluble salts and exchangeable sodium, both of which increase with depth.

[1] Joint contribution from the Gurabo Substation and the Department of Soils of this Station.

[2] Soil Scientist in Charge of the Gurabo Substation and Assistant Soil Scientist, respectively, Agricultural Experiment Station, University of Puerto Rico, Río Piedras and Gurabo, P.R. Appreciation is expressed to G. Acevedo, Research Assistant in soils who helped in some of the field and laboratory work.

[3] Italic numbers in partheses refer to Literature Cited, p. 277.

## METHODS

The sampling was done as a part of a more extensive study on the nature and properties of the major soils of Lajas Valley (*3*). Pits 4 feet wide, 4 feet long, and 6 feet deep were dug at 23 selected, scattered, and distant places mainly along the eastern and central sections of the lower Valley. The soils were described and sampled throughout each layer. Undisturbed soil cores were taken with a Uhland sampler, 3 inches in diameter by 3 inches in length. Four cores were taken from each layer.

Subsoil hydraulic-conductivity measurements were made on the undisturbed cores by recording the rate at which water moved through a column of saturated soil at a known head.

TABLE 1.—*Subsoil hydraulic-conductivity values in major soils of Lajas Valley Irrigation Development Project*

| Soil series | Samples | Mean hydraulic conductivity | Range of hydraulic conductivity values |
|---|---|---|---|
| | *Number* | *In. per hr.* | *In. per hr.* |
| Aguirre | 24 | 0.057 | <0.005–0.29 |
| Guánica | 16 | .046 | <.005– .09 |
| Fraternidad | 20 | .055 | <.005– .11 |
| Fe | 12 | .101 | <.005– .23 |
| San Antón | 8 | .220 | .11 – .33 |
| Santa Isabel | 4 | .050 | .05 |
| Jácana | 8 | .032 | <.005– .06 |

## RESULTS AND DISCUSSION

Table 1 gives mean hydraulic conductivity and the range of values for subsoils of the major soil series of the Lajas Valley. As can be observed, hydraulic conductivity is slow in all the subsoils. In magnitude they could be ranked: San Antón > Fe > Aguirre = Fraternidad = Santa Isabel > Guánica > Jácana.

The slow water movement in these subsoils can be explained on basis of the nature and size of the soil voids. Although all these subsoils have a high porosity, most of the pores are very small as revealed by water retention when low tensions develop (*3*). Furthermore, subsoil aggregates are very unstable (*2*), and disperse quickly upon wetting, thus clogging soil voids.

Previous studies have shown that the topsoil, usually 1 or 2 feet in depth, can conduct water rather well as compared to the subsoils (*3*) (fig. 1). In some Guánica soils water moves in the upper 2 feet at rates over 1 inch per hour; in some Fe, Fraternidad, and Aguirre soils extremely fast rates of over 5 inches have been recorded, more so in the uppermost 6-inch layer.

The slow hydraulic-conductivity values in the subsoils complicate the

management of the irrigated soils of the Lajas Valley. Comprehensive drainage and cropping programs must take account of this fact. The Jácana soils occurring at higher elevations throughout the Valley have better

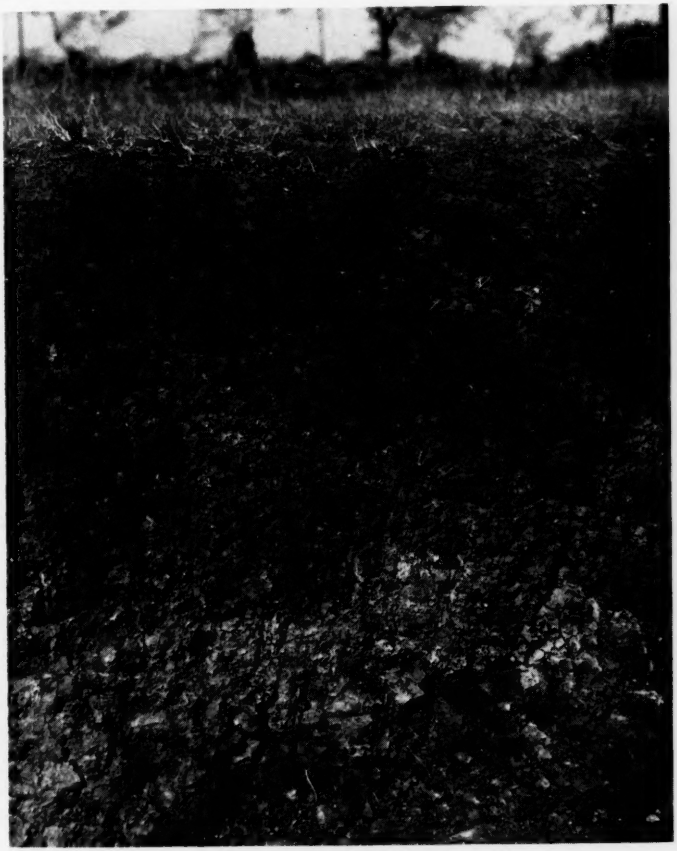

FIG. 1.—Most of the Lajas Valley soils have a topsoil with favorable structure that conducts water rather well. Subsoils are tighter, with weak unstable aggregates.

surface drainage than other soils. The Fraternidad and Fe soils (fig. 2), on the long, gently sloping alluvial fans rank next as to surface drainage, but in the Aguirre and Guánica soils of the lower Valley waterlogging would result if open channels were not available.

The exceedingly slow hydraulic-conductivity of subsoils together with

the very low stability of aggregates in most soils of the Valley constitute a large potential danger. Light, frequent irrigations gaged to conform with these limitations can be the key to successful farming over the Valley.

FIG. 2.—The Fraternidad and Fe soils on gently sloping lands have better surface drainage but subsoil hydraulic conductivity is slow.

**SUMMARY**

Data are presented here on the hydraulic conductivity of subsoils of major soils from the Lajas Valley Irrigation Drainage Project. The data reveal that subsoil hydraulic conductivity is very slow in all cases. In some cases favorable features are the gently sloping topography at the upper Valley and the fact that topsoils generally conduct water rather well. Careful soil-management and cropping programs should take account of these facts, recognizing the limitations involved.

**RESUMEN**

Se presentan aquí datos sobre la conductividad hidráulica en los subsuelos de los suelos de mayor importancia en el Valle de Lajas. Los datos revelan que el movimiento de agua en estos subsuelos es lento en todos los casos estudiados. La topografía, ligeramente inclinada en algunos casos, y el hecho de que el movimiento del agua en las capas superficiales de los suelos es bastante bueno, son factores favorables. Los programas sobre el manejo

de estos suelos y sobre las cosechas, deben tomar ventaja de estos hechos, reconociendo, al mismo tiempo, las limitaciones inherentes.

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# Identification of Various Micro-organisms Found in Sweetpotatoes and Guava

*Lilybett Valentín-Ramos*[1]

## INTRODUCTION

The processing of tropical fruits and vegetables is being extensively investigated at the Food Technology Laboratory of the Agricultural Experiment Station of the University of Puerto Rico. Many of these fruits and vegetables can either be hot-packed in cans or frozen. Information is lacking on suitable processing schedules for most of these products. In order to develop proper processing schedules, as well as adequate assay procedures to determine the contamination of frozen products, a research project is being carried out in this Laboratory to identify the natural flora generally present in the fruits and vegetables grown in Puerto Rico. This paper deals with the isolation and identification of organisms present in sweetpotatoes and guavas.

## MATERIALS AND METHODS

### SWEETPOTATOES AND GUAVAS

Sweetpotatoes of the U.P.R. 3 and Rico varieties were used. All samples were obtained from the Isabela Substation and harvested at 4½ months after planting.

Fresh guavas, at different degrees of ripeness were obtained from various orchards through the eastern portion of the Island.

### CULTURE MEDIA

Tryptone Glucose Extract Agar (Difco) and Nutrient Agar (Difco), respectively, were used for the isolation and storage of the micro-organisms obtained from guavas and sweetpotatoes. Special differential media were used for the characterization of the micro-organisms isolated.

### EQUIPMENT

A Waring Blendor was used to disperse the guava and sweetpotato in sterile water.

Inoculated media were incubated at 27°, 37°, and 55° C.

### SAMPLE PREPARATION

Guavas and sweetpotatoes were peeled under aseptic conditions and the cortex and flesh collected in separate sterile Petri dishes. The cortex was

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transferred to a sterile stainless steel Waring Blendor jar and dispersed in sterile water for 2–3 minutes. Two parts of sterile water was added per part of cortex.

Using this homogeneous suspension as the starting material, serial dilutions were prepared. Aliquots from the various dilutions were seeded in sterile Petri dishes to which warm Tryptone Glucose Extract Agar (Difco) was added. The medium was allowed to solidify and was incubated at 27°, 37°, and 55° C. for over 24 hours.

The same method described above was repeated with the flesh of both products. Guavas were studied at different degrees of ripeness.

TABLE 1.—*Characteristics of individual cells of organisms isolated from sweetpotato*

| Item | Characteristics of organism— | | | |
|---|---|---|---|---|
| | A | B | C | D |
| Forms | Long, thin rods | Long rods | Long rods, may be encapsulated | Long, thin rods |
| Size[1] | | | | |
| l. | 1.75–2.25 | 1.5–3.5 | 1.5–3.5 | 1.5–3.5 |
| w. | 0.5 –0.75 | 0.5–1 | 0.45–0.75 | 0.4–1 |
| Gram stain | + | + | + | + |
| Acid-fast stain | – | – | – | – |
| Movement | + | + | + | + |
| Spores | Ellipsoidal subterminal | Ellipsoidal subterminal. Sporangia may be swollen | Ellipsoidal central | Ellipsoidal central to para-central |

[1] Size in microns.

All colonies of apparently different organisms were separated and purified after the period of incubation was over.

Morphological and physiological characteristics of each micro-organism were determined. Final classification of the different organisms was carried out in accordance with Bergey's Manual of Determinative Bacteriology.

## RESULTS AND DISCUSSION

The results of the tests made for the classification of the bacteria isolated from sweetpotatoes are summarized on tables 1 to 4. It was possible to isolate four apparently different organisms identified by letters A to D.

Studying the characters of the individual cells (table 1) it was found that the four organisms appeared as long, motile, sporogenous, Gram-positive bacilli. Although the colonies belonging to the four organisms were similar in color and form (table 2) they varied in elevation, consistency,

and margin. All the organisms except B produced a white pellicle when grown on Nutrient Broth (Difco). It was found that the optimum growth temperature was around 30° C. These characteristics indicated that the organisms isolated from sweetpotatoes belonged to the Genus *Bacillus*.

Specific biochemical reactions were then studied to determine as closely as possible the species to which each of the four isolates belonged. The diameter of the vegetative rods (table 1); appearance of the protoplasm of young cells growing on glucose agar; growth on soybean agar (*2*)[2], 7-percent NaCl broth (*3*, *4*), tyrosine agar (*5*); citrate utilization; casein and starch hydrolysis; production of catalase, acetyl-methyl-carbinol and lecithinase (*6*) (table 4); and the fermentation of carbohydrates—primarily

TABLE 2.—*Morphology of the colonies of organisms isolated from sweetpotato*

| Item | Characteristics of organism— | | | |
|---|---|---|---|---|
| | A | B | C | D |
| Form | Small, circular irregular | Confluent | Circular, confluent | Circular, irregular, confluent |
| Elevation | Raised | Raised | Effuse or umbonate | Effuse or umbonate |
| Margin | Entire | Ramose | Entire or erose | Crenate or erose |
| Consistency | Opaque, smooth | Smooth | Finely granular | Coarsely granular |
| Color | White | White | White | White |
| Growth on Broth | White pellicle | Faintly diffused; sediment | White, rough pellicle | White, smooth pellicle |

glucose, lactose, sucrose, mannitol, arabinose, xylose, and glycerol—(table 3), were the main criteria used for differentiation into species.

Organisms A, C, and D have a diameter of less than 0.9 $\mu$. They show a good, spreading growth on glucose agar with young cells staining uniformly. They grow well on soybean agar, 7-percent NaCl broth, tyrosine agar, citrate medium, and anaerobic glucose broth under anaerobic conditions. They have a positive reaction to hydrolysis of gelatin and casein and a negative reaction to starch hydrolysis. They produce catalase and acetyl-methyl-carbinol, but give a negative lecithinase test. Organisms A, C, and D appear very similar to *Bacillus licheniformis*.

Organism B has a diameter of over 0.9 $\mu$. It grows well on glucose agar, producing large, vacuolated cells. It produces catalase and acetyl-methyl-carbinol. It has the ability to reduce nitrates and hydrolyze gelatin, casein,

[2] Italic numbers in parentheses refer to Literature Cited pp. 289–90.

and starch, and gives a positive lecithinase test. This organism does not produce acid from arabinose, xylose, or mannitol. It can be concluded that organism B is similar to *Bacillus cereus*.

TABLE 3.—*Fermentation reactions of organisms isolated from sweetpotato*

| Carbohydrate | Characteristics of organism— | | | |
|---|---|---|---|---|
| | A | B | C | D |
| Arabinose | − | − | − | − |
| Rhamnose | − | − | − | − |
| Xylose | − | − | − | − |
| Glucose | + | + | + | + |
| Fructose | + | + | + | + |
| Galactose | + | + | − | − |
| Mannose | + | ± | − | + |
| Lactose | + | ± | + | − |
| Sucrose | ± | − | ± | ± |
| Maltose | − | + | − | ± |
| Trehalose | ± | + | − | − |
| Melibiose | − | − | − | − |
| Raffinose | − | − | − | − |
| Melezitose | − | − | − | − |
| Starch | − | + | − | − |
| Inulin | − | − | − | ± |
| Dextrin | − | + | − | − |
| Glycogen | − | + | − | − |
| Glycerol | ± | − | − | ± |
| Erythritol | − | − | − | − |
| Adonitol | − | − | − | − |
| Mannitol | + | − | − | ± |
| Sorbitol | − | − | − | ± |
| Dulcitol | − | − | − | − |
| Salicin | + | + | − | ± |
| Aesculin | + | + | − | ± |
| Alpha-methyl glucoside | − | − | − | − |

## SWEETPOTATOES

### GUAVAS

The results of tests carried out on guavas are summarized on tables 5 to 8. It was possible to isolate nine cultures, seven of which were motile, sporogenous Gram-positive or Gram-variable rods of varying sizes; and two Gram-positive cocci with cells arranged in irregular masses (table 5). The rods numbered from 1 to 7 can grow under aerobic or anaerobic conditions preferably at temperatures close to 30° C. The cocci presented a more

TABLE 4.—*Other biochemical reactions of organisms isolated from sweetpotato*

| Reaction | Characteristics of organism— | | | |
|---|---|---|---|---|
| | A | B | C | D |
| Gelatin hydrolysis | + | + | + | + |
| Indole production | − | − | − | − |
| Nitrate reduction | + | + | + | + |
| Catalase production | + | + | + | + |
| Decomposition of urea | − | − | − | − |
| Citrate utilization | + | + | + | + |
| Casein hydrolysis | + | + | + | + |
| $H_2S$ production | − | − | − | − |
| Litmus milk reaction | Peptonization, slow reaction | Peptonization, fast reaction | Peptonization, fast reaction | Peptonization, fast reaction |
| Methyl-red test | ± | + | − | − |
| Voges-Proskauer test | + | + | + | + |
| Growth on 7-percent NaCl broth | Good; granular pellicle | Good | Good; pellicle | Good |
| Growth on Anaerobic Glucose Broth | Good; pellicle | Good; diffused | do. | Good; pellicle |
| Growth on alkaline anaerobic nitrate agar | Good; z+ | Good; + | Good; z+ | Good; + |
| Growth on Proteose Peptone Acid Agar | Fair | Very good | Very good | Do. |
| Growth on Tyrosine Agar | Good; white colonies | Good | Very good; white colonies | Very good; white colonies |
| Growth on soybean agar | Good | do. | Good, flat, dry growth | Good, flat, dry growth |
| Growth on Glucose Agar | Good; spreading | do. | Very good; spreading | Good; spreading |
| Gram-stain reaction on Glucose Agar | Small Gram + rods; stained uniformly | Large, vacuolated Gram + rods | Small, encapsulated, Gram variable rods | Small, Gram + rods, stain uniformly |
| Lecithinase test | − | + | − | − |
| Growth on potato plugs | None | Flat, moist, off-white color | Dry, rough wrinkled, beige growth | Dry wrinkled cream-pink color |

TABLE 5.—*Characteristics of individual cells of organisms developed from guava*

| Item | Characteristics of organism— | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Form | Long, thin rods, beaded | Long rods | Small rods | Long, thin rods | Long, thick rods | Large rods, beaded | Small rods | Cocci | Cocci |
| Size[1] | | | | | | | | | |
| l. | 4–7 | 1.5–3.5 | 1–2.5 | 2.5 | 2.5–6 | 3–4 | 1–2.5 | | |
| w. | 1 | 0.5–1 | 0.4–0.5 | 0.5–0.75 | 0.75–1.25 | 0.75–1 | 0.35–0.5 | | |
| Gram stain | Variable | + | Variable | Variable | + | + | + | + | + |
| Acid-fast stain | − | − | − | − | − | − | − | − | − |
| Movement | + | + | + | + | + | + | + | − | − |
| Spores | Ellipsoidal; subterminal | Spherical to ellipsoidal; subterminal | Ellipsoidal; subterminal | Ellipsoidal; subterminal; sporangia may be swollen | Spherical; subterminal | Ellipsoidal subterminal; sporangia slightly swollen | Ellipsoidal; central | | |

[1] Size in microns.

TABLE 6.—*Morphology of the colony of organisms isolated from guava*

| Item | Characteristics of organism— | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Form | Large, circular | Large, circular | Tiny, circular, confluent | Circular, small | Large, circular, confluent | Large, circular, confluent | Spreading | Circular, small | Circular, small |
| Elevation | Low convex or convex | Low convex or convex | Raised | Low convex | Raised | Raised or convex | Raised | Convex | Low convex |
| Margin | Entire or erose | Entire or erose | Entire or undulate | Entire or irregular | Entire | Undulate or ramose | Entire or curled | Entire | Entire |
| Consistency | Smooth | Smooth | Rough, dry, or smooth, opaque | Smooth, opaque | Opaque, smooth | Opaque | Opaque or translucent | Smooth | Smooth |
| Color | Yellow | Yellow | White or yellow | Yellow | Beige to yellow | White | White | Creamy yellow | White |
| Growth on broth | Granular, scant | Diffused, scant | Granular, scant | Diffused, scant | Diffused, scant | Diffused, scant | Diffused, scant | Diffused | Granular, diffused |

luxuriant growth at 37° C. under aerobic conditions, although they developed under anaerobic conditions on glucose broth.

Observing the cellular morphology (table 5) and the characteristics of growth on solid and liquid media (table 6) it was evident that the rods

TABLE 7.—*Fermentation reactions of organisms isolated from guava*

| Carbohydrate | Characteristics of organism— | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Arabinose | ± | + | − | − | ± | ± | − | ± | ± |
| Rhamnose | − | − | − | − | − | − | − | − | − |
| Xylose | ± | ± | − | − | ± | − | − | ± | ± |
| Glucose | + | + | + | + | + | + | + | + (pH 5.0) | + (pH 5.0) |
| Fructose | ± | + | + | ± | + | + | + | + | + |
| Galactose | + | + | − | ± | ± | ± | + | ± | + |
| Mannose | + | ± | ± | − | ± | − | + | + | + |
| Lactose | + | + | − | ± | + | ± | − | + | + |
| Sucrose | ± | ± | − | ± | + | + | ± | ± | + |
| Maltose | + | + | − | + | + | + | − | + | + |
| Trehalose | − | ± | − | − | ± | + | ± | ± | − |
| Melibiose | − | − | − | + | ± | − | − | − | − |
| Raffinose | + | + | − | − | + | − | − | − | − |
| Melezitose | − | − | − | − | − | − | − | − | − |
| Starch | ± | ± | − | ± | + | − | − | − | ± |
| Inulin | − | ± | − | − | − | − | − | − | ± |
| Dextrin | + | + | − | ± | + | + | − | − | ± |
| Glycogen | − | + | − | + | + | − | − | − | + |
| Glycerol | − | − | − | + | − | − | − | + (Slow) | + (Slow) |
| Erythritol | − | − | − | − | − | − | − | − | − |
| Adonitol | − | − | − | − | − | − | − | − | − |
| Mannitol | ± | − | − | − | ± | − | ± | + | − |
| Sorbitol | + | − | − | − | − | − | − | − | − |
| Dulcitol | − | − | − | − | − | − | − | − | − |
| Salicin | − | − | + | − | − | − | + | − | − |
| Aesculin | − | ± | ± | − | ± | − | ± | − | ± |
| Alpha-methyl glucoside | − | − | − | − | − | − | − | − | − |

isolated from guavas belonged to the Genus *Bacillus*; and the cocci were members of the Family Micrococcaceae.

To differentiate the organisms into species a study of their biochemical reactions was carried out. Fermentation reactions on carbohydrates (table 7); hydrolysis of gelatin, casein, and starch; production of indole, hydrogen sulfide, catalase, and acetyl-methyl-carbinol; reaction on nitrates, citrate,

TABLE 8.—*Other biochemical reactions of organismus isolated from guava*

| Reaction | Characteristics of organism— | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Gelatin hydrolysis | + | + | + | + | + | + | + | − | − |
| Indole production | − | − | − | − | − | − | − | − | − |
| Nitrate reduction[1] | Z+ | Z+ | + | Z+ | Z+ | + | Z+ | + | Gas Z+ |
| Catalase production | + | + | + | + | + | + | + | + | + |
| Decomposition of urea | − | − | − | − | − | − | − | + | + |
| Citrate utilization | + | + | + | + | + | + | + | − | − |
| Casein hydrolysis | + (fast) | + | + | + | + | + | + | − | − |
| $H_2S$ production | − | − | − | − | − | − | − | − | − |
| Litmus milk reaction | Peptonization, alkaline | Peptonization | Peptonization, alkaline | Peptonization, alkaline | Peptonization | Peptonization | Peptonization | Acid | Acid, coagulation |
| Methyl-red test | ± | -- | ± | ± | ± | + | ± | − | + |
| Vogues-Proskauer test | − | − | + | − | − | − | + | + | − |
| Growth on 7-percent NaCl broth | Good | Good | Good, pellicle | Good | Poor | Fair | Fair | Diffused, ring | Diffused |
| Growth on Anaerobic Glucose Broth | Poor | Poor, sediment | Fair, pellicle | Poor | Poor, sediment | Good, sediment | do. | Flocculation sediment, pellicle | Do. |
| Growth on Alkaline Anaerobic Nitrate Agar | Z+ | Z+ | Z+ | Z+ | Z+ | + | Z+ | | |
| Growth on Proteose Peptone Acid Agar | Good | Better than on nutrient agar | Fair | Fair | Good | Good | Poor | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| teose Peptone Acid Agar | | nutrient agar | | Fair | Good | Good | Poor | | |
| Growth on Tyrosine Agar | Good, white colony, dark agar | Good, smooth white colony, dark agar | do. | Good, dark agar | Good, amber color agar | do. | Fair | | |
| Growth on Soybean Agar | Good | Good, moist | Good | Good | Good | do. | Good | | |
| Growth on Glucose Agar | Fair, less than on nutrient agar | Fair | Good, spreading | Poor | Good, mucoid | do. | Good, spreading | | |
| Gram stain from Glucose Agar | Large, thick Gram ± rods, beaded | Large, Gram + rods, uniformly stained, capsule | Large, Gram-variable rods, beaded | Large, Gram-variable rods, stain uniformly | Short, thick Gram ± rods bipolar-stain, capsule | Long, thick, Gram + rods, beaded | Small, Gram ± rods stain, uniformly | | |
| Lecithinase test | Undetermined | − | − | − | − | + | − | | |
| Growth on potato plugs | Moist, abundant yellowish white | Moist, yellow | − | Flat, moist white | Abundant moist, beige-white | Moist, white, abundant | − | | |
| Starch hydrolysis | − | + | − | + | − | + | − | − | − |
| Coagulate test | | | | | | | | − | − |
| Blood hemolysis | | | | | | | | − | Beta-hemolysis |
| Growth on $NH_4 \cdot H_2PO_4$ agar | | | | | | | | − | − |
| Sodium hippurate utilization | | | | | | | | − | − |

[1] Nitrate-reduction test was done on Nitrate Agar (Difco) incubated at 30° C. A distinct pink or red color (+) indicated the presence of nitrite. If no color appears in tubes with abundant growth, zinc dust is added. The presence of the distinct red color (Z+) indicates the reduction of nitrate to nitrite.

urea, and litmus milk; and growth on a salt-containing medium (table 8) were determined for each culture.

To characterize the species of the Genus *Bacillus* other tests besides the ones mentioned above were carried out. The ability to grow on such media as proteose peptone acid agar (Thermoacidurans Agar Difco), tyrosine agar, soybean agar, glucose agar, and anaerobic glucose broth (table 8) was determined.

Organisms 1 and 5 with a diameter of over 0.9 $\mu$, with cells appearing vacuolated when grown on glucose agar, unable to produce acetyl-methyl-carbinol, and lecithinase (table 8), and fermenting glucose, sucrose, and mannitol (table 7) appeared to be similar to *Bacillus megatherium*.

Organism 6 is also a large bacillus with a diameter of over 0.9 $\mu$ and vacuolated protoplasm when grown on glucose agar. The facts that it did not ferment mannitol or xylose (table 7), and that it produced acetyl-methyl-carbinol and lecithinase (table 8) indicated its similarity to *Bacillus cereus*.

Organisms 2, 3, 4, and 7 are all smaller with a diameter of less than 0.9 $\mu$ and all stain uniformly when grown on glucose agar. Organisms 3 and 7 vary in size from 1 to 2.5 $\mu$ in length by 0.35 to 0.5 $\mu$ in width. Both of them grow well on soybean agar and on 7-percent NaCl broth. They do not hydrolyze starch, do not produce acetyl-methyl-carbinol; but produce lecithinase. It can be said that organisms 3 and 7 are similar to *Bacillus pumilus*.

Organisms 2 and 4 grow well on soybean agar and 7-percent NaCl broth, but show poor development on anaerobic glucose broth. When grown on tyrosine agar they produce a pigment which turns the agar dark. These organisms are classified as *Bacillus subtilis* var. *niger*.

Organisms 8 and 9 appeared as nonmotile, Gram+ spherical cells arranged in irregular masses. Both of them produce small, circular, smooth colonies with entire margin, creamy yellow to white in color (table 6). Both give an acid reaction in litmus milk and organism 9 caused coagulation also. Organism 8 showed no hydrolysis of starch, aesculin, and sodium hippurate (*7*). Both of them reduced nitrate, and give a positive reaction to production of catalase and decomposition of urea. Neither one utilized $NH_4H_2PO_4$ (*8*, *9*) as a source of nitrogen. Organism 9 shows beta-hemolysis on blood agar plates; not so organism 8. The coagulase test for both of them was negative. Although various characteristics shown by organisms 8 and 9 appear to diverge from those expected of a *Staphylococcus aureus*; these organisms appear closer to this Genus than to any other of the Genera encountered in the Family Micrococcaceae.

All the organisms isolated from guavas and sweetpotatoes were encountered in the cortex. This is to be expected inasmuch as the isolates

are organisms commonly found in nature whose habitat is the soil, dust particles, and plant surfaces.

## SUMMARY

A study was undertaken for the purpose of obtaining information about the flora normally encountered in sweetpotatoes and fresh guavas.

Homogeneous suspensions of the cortex and flesh of both products were prepared in sterile water and used for the isolation of micro-organisms. Isolations were carried out on Tryptone Glucose Extract Agar plates incubated at 27°, 37°, and 55° C.

An extensive study of the morphological and physiological characteristics of each micro-organism was carried out in accordance with the 7th edition of the Bergey's *Manual of Determinative Bacteriology* (1957).

It was found that the organisms isolated from sweetpotatoes are similar to the Genera *Bacillus cereus* and *B. lichemformis*. Those isolated from guava were classified as *Bacillus megatherium*; *B. cereus*; *B. pumilus*; *B. subtilis* var. *niger*; and *Staphylococcus aureus*.

## RESUMEN

El presente trabajo incluye los datos obtenidos de un estudio que se llevó a cabo para obtener información acerca de la flora que se encuentra normalmente en la guayaba y en la batata fresca.

Suspensiones homogéneas de la corteza y la pulpa de ambos productos fueron preparados en agua estéril, las cuales fueron usadas para aislar los microorganismos.

Se hizo un estudio abarcador de los caracteres morfológicos y fisiológicos de cada organismo para lo cual sirvió de guía la Séptima Edición del *Manual de Bacteriología de Bergey* (1957).

Se encontró que los organismos aislados de la batata son similares a los de los géneros *Bacillus cereus* y *B. lichemformis*. Los de la guayaba se clasificaron como *Bacillus megatherium*; *B. cereus*; *B. pumilus*; *B. subtilis* var. *niger* y *Staphilococcus aureus*.

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# Control of Greenhouse Thrips *Heliothrips Haemorrhoidalis* (Bouché), with Systemic Insecticides

*Silverio Medina Gaud*[1]

## INTRODUCTION

The greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), Order Thysanoptera, is a fairly common species in Puerto Rico, although it has a worldwide distribution. Many plants, ornamentals and others, are damaged at times by this thrips. It is very common during dry seasons of the year or under special ecological conditions.

## THE INSECT

### DESCRIPTION

The adult thrips is blackish brown, with light-colored appendages. The head and central portion of the body are covered with a distinct deep network of lines or wartlike elevations. The length of the mature insect is about $\frac{1}{20}$ to $\frac{1}{24}$ of an inch. The wings are slightly clouded, but without bands, and the antennae are slender and pronouncedly needlelike at the tip. On account of its peculiar markings it is one of the most distinguishable species of thrips and can be easily identified (fig. 1).

The young larva or nymph is white with red eyes, turning yellow when older; the same as the pupae, which also has red eyes. (*4*, *5*)[2]

### TYPE OF INJURY

The greenhouse thrips, both the nymph and adult, rasp the surface tissues of the parts of the plants attacked, particularly on the foliage, feeding on the juices thus liberated. As a result of this action, the surface cells die, becoming white in color. This species is found in colonies, all stages being present on the leaves, particularly on the undersides. The peculiar and familiar silvery or bleached appearance quickly becomes evident after feeding has occurred on a leaf. When these insects become abundant they are capable of producing an intense chlorosis of the leaves of the plant attacked, followed by wilting and dropping. The young nymphs excrete from the tip of the abdomen a ball of brown semiliquid material which they carry around, later on depositing it on the feeding surfaces. This secretion gives an unsightly appearance to the foliage and, thus reducing the

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[2] Italic numbers in parentheses refer to Literature Cited, p. 294.

commercial value, specially of ornamentals. The black or brownish dots of excrement typical of thrips feeding activity are also a ready means of identifying the injury.

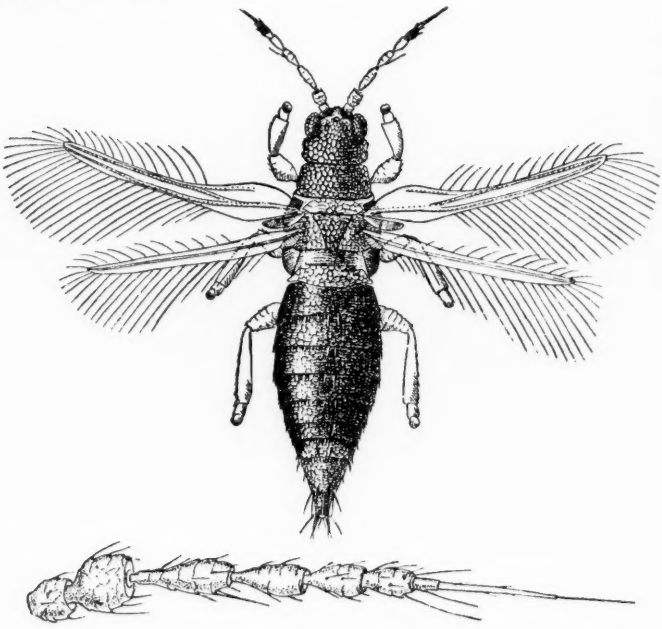

FIG. 1.—Greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché). Adult female enlarged about 50 diameters, and greatly enlarged drawing of antenna underneath, (After Russell: USDA Farmers' Bulletin No. 1306, Feb. 23, 1923).

HOSTS

In Puerto Rico the greenhouse thrips has been listed on the introduced tree, *Barringtonia speciosa* Forst, and on wild and cultivated cottons, *Gossypium hirsutum* L. and *G. barbadense* L.; on cacao, *Theobroma cacao* L.; grapefruit, *Citrus maxima* (Burm.) Merril; orange, *C. sinensis* (L.) Osbeck; and on coconut palm, *Cocos nucifera* L. It has been reported also as a pest of cinchona, *Cinchona calisaya* Wedd and *C. ledgeriana* (*1, 2, 3, 4*). Three new host records are hereby added. These are "brillantina", *Iresine Lindenii* Van Houte; croton, *Codiaeum variegatum* (L.) Blume, and "capa de obispo", *Acalypha Wilkesiana* Muell. Arg.

## MATERIALS AND METHODS

A control experiment was conducted on August 16, 1957, to evaluate the effectiveness of systemics on the control of the pest. The systemic insecti-

cides used were: Thimet (47.5 percent, containing 4 pounds of the technical compound per gallon); Systox; Bayer 23129; and Bayer 19639. These last three chemicals contained 2 pounds per gallon of the active ingredient. All the insecticides were used at three concentration levels: 1–400; 1–600; and 1–800.

The test was conducted on croton, *Codiaeum variegatum* (L.) Blume, heavily infested with the thrips. The croton plants were rooted in sand and then transplanted to 5-inch clay pots. Four plants, varying in height from 12 to 18 inches, were used for each treatment.

TABLE 1.—*Results of the control of* **Heliothrips haemorrhoidalis** *Bouché by means of systemic insecticides*

| Insecticide used | Dilution | Number of live thrips on 12 leaves— | | | | | |
|---|---|---|---|---|---|---|---|
| | | Before treament, Aug. 16, 1957 | | After treatment | | | |
| | | | | Aug. 20, 1957 | | Oct. 14, 1957 | |
| | | Adults | Nymphs | Adults | Nymphs | Adults | Nymphs |
| Thimet, 47.5 percent | 1–400 | 30 | 61 | 0 | 0 | 0 | 0 |
| Do. | 1–600 | 141 | 126 | 0 | 0 | 0 | 0 |
| Do. | 1–800 | 158 | 117 | 0 | 0 | 0 | 0 |
| Systox, 2 lb./gal. | 1–400 | 9 | 87 | 0 | 0 | 0 | 0 |
| Do. | 1–600 | 106 | 116 | 0 | 0 | 0 | 0 |
| Do. | 1–800 | 70 | 37 | 0 | 0 | 0 | 0 |
| Bayer 23129, 2 lb./gal. | 1–400 | 19 | 169 | 0 | 0 | 0 | 0 |
| Do. | 1–600 | 100 | 91 | 0 | 0 | 0 | 0 |
| Do. | 1–800 | 73 | 94 | 0 | 0 | 11 | 0 |
| Bayer 19639, 2 lb./gal. | 1–400 | 139 | 204 | 0 | 0 | 0 | 0 |
| Do. | 1–600 | 98 | 160 | 0 | 0 | 0 | 0 |
| Do. | 1–800 | 58 | 74 | 0 | 0 | 0 | 0 |
| Check (nontreated) | | 104 | 216 | 78 | 120 | 45 | 79 |

A pretreatment count was conducted on three leaves per plant, making a total of 12 leaves for each treatment. The insecticidal materials were applied as a soil drench, using 5 liquid ounces per pot of the already prepared chemicals at the different levels. Results of the test were determined by counting the number of live thrips on the same leaves selected for pretreatment counts. Weekly counts were continued for 2 months to determine the residual action of the chemicals under test.

## RESULTS

Infestation counts were made on August 16, just before application of insecticides given on the same date. From there on, counts were made on August 20, and thereafter at weekly intervals up to October 14.

As shown in table 1, all insecticidal treatments were effective in con-

trolling the thrips while the check plants remained infested. It may be noticed that Bayer 23129 compound at a concentration of 1–800 lost its effectiveness at the end of 1 month. All other treatments produced freedom from thrips for 2 months.

Weekly infestation counts after August 20 are not represented in table 1 because no thrips were found until October 14, as shown.

## SUMMARY

The greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché) is one of the most common and injurious insect pest of many plants in Puerto Rico. This is specially true during dry seasons and under special ecological conditions. Three new host plants were added to the existing list and the insect is briefly described. Four systemic insecticides were tested namely: Thimet, Systox, Bayer 23129, and Bayer 19639. Using three concentration levels of each chemical perfect control of the thrips was obtained for a period of 2 months, with exception of Bayer 23129 (1–800) which permitted reinfestation at the end of 1 month.

## RESUMEN

El trípido de invernáculo, *Heliothrips haemorrhoidalis* (Bouché) es uno de los insectos más perjudiciales a muchas plantas en Puerto Rico. Esto es especialmente cierto durante épocas de sequía o bajo condiciones ecológicas especiales. Se incluye una corta descripción del trípido de invernáculo y se añaden tres nuevas plantas hospedadoras a la lista existente.

Cuatro insecticidas sistémicos fueron evaluados, usando tres niveles de concentración. Estos fueron: Thimet, Systox, Bayer 23129, y Bayer 19639. Todos los tratamientos combatieron al trípido eficazmente por un período de dos meses, con la excepción de la concentración de 1–800 del insecticida Bayer 23129. En este último caso las plantas tratadas se reinfestaron al final del primer mes.

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# Preliminary Study on the Control of the Cottony-Cushion Scale (*Icerya purchasii* Maskell,) by Means of Insecticides

*Slverio Medina Gaud*[1]

## INTRODUCTION

*Icerya purchasii* Maskell, or the cottony-cushion scale, was first officially recorded in Puerto Rico by W. A. Hoffman on trees of beefwood or Australian pine, *Casuarina equisetifolia* Forst at San Juan (*1*).[2] This introduced species, which for a short time appeared to be a serious pest to our agriculture, is practically under natural control. Since its introduction it has spread widely around the Island; fortunately, it has become less destructive because today it is practically controlled by its natural parasites and predators when it becomes abundant. Today, with the advent of modern and effective insecticides, it is controlled very readily.

A more complete historical account of this insect pest is found in an interesting article published by Wolcott and Seín (*2*) in 1933.

## DESCRIPTION AND CHARACTERISTICS

### THE INSECT AND ITS CONTROL

The general appearance of the insect, however, is strikingly odd owing to waxy excretions from the ventral plate of the adult female. The waxy material constitutes the egg sac. The eggs are laid in the waxy secretion. After the egg sac is fully formed the female may measure about 3/8 of an inch in length. The sac is white and grooved or fluted.

The young scales are reddish-brown and very active, and spread by their own efforts and by the agency of the winds, as well as birds and other insects. Some yellow waxy threads often extend from the body and cause a hairy appearance.

The female insect is, for the most part, reddish-orange in color, more or less spotted with white or lemon (fig. 1).

The winged male is rather large for a coccid and has a reddish body with smoky wings.

### NATURAL ENEMIES

The more important natural enemy of the cottony-cushion scale is the introduced Australian ladybeetle, *Rodolia cardinalis* Mulsant. This predator,

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[2] Italic numbers in parentheses refer to Literature Cited p. 299.

plus various native ones and other insect parasites, some of which are the following: the lacewing fly, *Chrysopa collaris* Schneider; the introduced agromyzid fly, *Cryptochaetum iceryae* Williston; the phorid fly, *Syneura cocciphila* Coquillet; the coccinellid beetles, *Decadiomus pictus* Chapin and *Cycloneda sanguinea* L., keep the insect pest at fairly low levels.

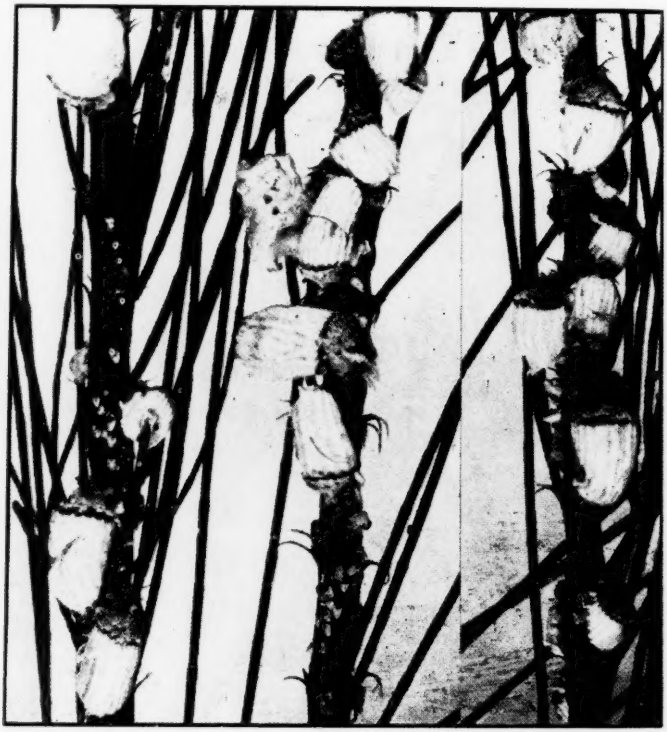

FIG. 1.—The cottony-cushion scale, *Icerya purchasii* Maskell, on twigs of australian pine, *Casuarina equisetifolia* Forst.

*Spicaria javanica* Bally, an entomogenous fungus, has been also recorded as an enemy of this pest.

## TYPE OF INJURY

The cottony-cushion scale is a small inactive insect that feeds on the sap of the leaves and twigs of the plants or trees it attacks. Heavily infested plants appear unhealthy and produce very little new growth. The foliage

develops chlorotic areas and may drop prematurely and a portion of the twigs and branches may be killed. The fluted scales exude a great quantity of honeydew, and trees badly attacked by it are covered by sootie-mold and various species of ants.

### HOSTS

The following plants and trees are recorded as being infested by this scale insect in Puerto Rico:

*Acalypha Wilkesiana* Muell. Arg.—"capa de obispo"
*Adenoropium multifidum* (L.) Pohl—"Don Tomás"
*Cajan indicus* (L.) Millsp.—"gandures"
*Callophyllum antillanum* Britton—"María"
*Capsicum annuum* L.—"pimiento"
*Citrus aurantifolia* (Christm.) Swingle—"lima"
*C. maxima* (Burm.) Merril—"toronja"
*C. sinensis* (L.) Osbeck—"china"
*Erythrina glauca* Willd.—"bucaré"
*Hibiscus rosa-sinensis* L.—"amapola"
*Isandrina emarginata* (L.) Britton & Ross—"vela de muerto"
*Pithecellobium dulce* (Loxb.) Benth.—"guamá americano"
*Polyscias Guilfoylei* (E. March) Dene. & Pl.—"gallego"
*Neltuma* (*Prosopis*) *juliflora* (D.C.) Raf.—"bayahonda"
*Malpighia punicifolia* L.—"acerola" (new host record)

### DISTRIBUTION

Australia is said to be the original home of the fluted-scale, from whence it passed to New Zealand and subsequently into South Africa, Fiji, the Sandwich Island, the West Indies, Continental United States and into many parts of Europe (*3*, *4*).

## EXPERIMENTAL MATERIAL AND METHODS OF CONTROL

We cannot depend always or exclusively upon biological control. Sometimes the use of insecticides becomes necessary for a better and more rapid means of control of the insect's outbreaks which occur frequently. With this in mind a control experiment was begun April 25, 1957, in order to evaluate the effectiveness of two insecticides against this insect pest in a sudden outbreak occurring at La Catalina Nurseries, of the U.S. Forest Service, at El Yunque Range. The two insecticides were: Parathion, wettable powder containing 15 percent of the active ingredient per pound, used at the rate of 1½ pounds in 100 gallons of water; and Malathion, wettable powder containing 25 percent of the active ingredient, used at the rate of 2 and 4 pounds in 100 gallons of water.

Experimental control treatments were made on an 80-foot Australian pine seedbed heavily infested with the cottony-cushion scale. The seedbed was divided into 16 plots, 5 × 3 feet. The treatments were replicated four times. The Australian pine trees were from 1 to 2 feet high. All insecticides were applied with a knapsack sprayer.

## RESULTS

Results were determined by counting the number of live scales before and after the treatment, found on a total number of pine trees in a square-foot area chosen at random in each plot. After 8 days of the application of insecticides perfect control was found for all adult scales with both insecticides, while the scales in the check continued alive (table 1).

TABLE 1.—*Results on the control of* **Icerya purchasii** *Maskell by means of Parathion and Malathion*

| Insecticide | Dilution | Number of live scales[1] in 1 square foot for each treatment | | |
|---|---|---|---|---|
| | | Before treatment, Apr. 21, 1957 alive | After treatment, May 3, 1957 | |
| | | | Dead | Alive |
| Parathion | 1½ lb. in 100 gal. water | 208 | 181 | 0 |
| Malathion | 2 lb. in 100 gal. water | 159 | 155 | 0 |
| Do. | 4 lb. in 100 gal. water | 226 | 222 | 0 |
| Check | Nontreated | 206 | 0 | 206 |

[1] The counts are based on adult scales and crawlers.

It was observed, however, that the insecticides were not effective in the control of the eggs, since many of them were hatching and crawlers were found around. So, for an effective control, one or two additional sprayings at 15-day intervals are necessary to destroy the young as they hatch.

## SUMMARY

The cottony-cushion scale, *Icerya purchasii* Maskell, is one of the soft scales that attack a large variety of plants and trees in our Island. A series of host plants are listed and the insect is briefly described. Its distribution and natural enemies are also listed. Two insecticides, namely Parathion and Malathion, were tested for the control of the cottony-cushion scale in Australian pine, *Casuarina equisetifolia* Forst. Total control was obtained for all adult scales and crawlers with both insecticides, while in the checks both stages continued alive. It was found that the insecticides were not effective in the control of the eggs.

## RESUMEN

La cochinilla blanca, *Icerya purchasii* Maskell, es una queresa blanda que ataca a una gran variedad de plantas y árboles en Puerto Rico. Se describe el insecto brevemente y se incluye una lista de plantas hospedadoras. También se informa sobre su distribución y sobre sus enemigos naturales. Se probaron los insecticidas Paración y Malación para combatir esta queresa. Se logró un control completo de las formas adultas y jóvenes de la misma, mientras los testigos no tratados permanecieron infestados. Se encontró que los insecticidas mencionados no son eficaces para el control de los huevos de esta queresa.


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(*Continued from inside front cover*)

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A. Riollano, M.S., Agronomist In Charge
R. Abrams, M.S., Assistant Plant Breeder
O. Crespo López, B.S., Research Assistant in Agronomy
L. B. Ortiz, M.S., Associate Agronomist and Administrative Assistant
A. Pérez, B.S., Research Assistant in Horticulture
E. Pérez Rivera, B.S., Research Assistant in Agronomy
C. Ramos Caro, B.S., Research Assistant in Agronomy
H. Sánchez Correa, B.S., Research Assistant in Horticulture

*Lajas Substation*

A. Eschenwald-Hess, M.S., Agricultural Engineer In Charge
L. Almodóvar Vega[3], B.S., Research Assistant in Agronomy
I. Carlo, M.S., Assistant Animal Husbandman
F. Díaz Irizarry, B.S., Research Assistant in Irrigation Engineering
J. García Albino, B.A., Research Assistant in Chemistry
R. Irizarry, B.S., Assistant Agronomist
M. Martínez, B.S., Research Assistant in Agronomy
R. Mendoza Barbosa, B.S., Assistant Animal Husbandman
J. Ortiz Véles, M.S., Assistant Drainage Scientist
M. Pérez Zapata, B.S., Research Assistant in Agronomy
J. Quiñones, B.S., Research Assistant in Plant Breeding
A. Ramírez Ortiz, B.S., Research Assistant in Animal Husbandry
M. Rico, M.S., Assistant Horticulturist
M. Rojas Daporta, M.S., Associate Animal Husbandman
E. Rosado Carbó, V.M.D., Associate Veterinarian
F. Silvestry, B.S., Research Assistant in Agronomy
J. H. Sanfiorenzo, M.S., Assistant Animal Husbandman
J. Torres Más, M.S., Research Assistant in Agronomy
R. Vázquez, M.S., Assistant Irrigation Scientist

*Gurabo Substation*

M. A. Lugo-López, Ph.D., Soil Scientist In Charge
A. Acosta Matienzo, M.S., Research Assistant in Horticulture
J. E. Barbosa, B.S., Research Assistant in Agronomy
E. G. Boneta, B.S., Research Assistant in Agronomy
M. Capiel, M.S., Assistant Soil Scientist
C. González Molina, M.S., Assistant Plant Breeder
L. López Matos[2], M.S., Assistant Pathologist
M. Manzano, B.S., Assistant Biochemist
C. Ortiz Lugo, B.S., Associate Agronomist and Administrative Assistant
E. Reyes Soto, B.S., Research Assistant in Agronomy
A. Sierra, B.S., Research Assistant in Agronomy
J. Véles Santiago, B.S., Research Assistant in Horticulture

*Fruit Substation, Juana Díaz*

C. J. Clavell, B.S. Associate Horticulturist In Charge
G. C. Jackson, M.S., Assistant Horticulturist
J. López García, B.S., Research Assistant in Horticulture

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[1] As of September 1, 1959.
[2] On leave to pursue studies.
[3] On other types of leaves.
[4] Collaborators USDA.